EFFECTS OF INCISING ON TREATABILITY AND LEACHABILITY OF CCA-C-TREATED EASTERN HEMLOCK

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ABSTRACT

Incising is used to increase exposed wood surface and improve uptake and penetration of preservative during pressure treatment of refractory species. However, incising may also cause increased leaching of preservative when the wood is placed in service. This study compared the rate of leaching from unincised eastern hemlock to that of wood that had been incised to two depths and with two density patterns. Incising greatly increased both the penetration and retention of preservative in the incised wood compared to unincised wood. Doubling the depth of the incisions further improved retention and penetration, but doubling the density of the incisions appeared to benefit primarily the uniformity of preservative penetration. Incising did not increase the percentage of copper, chromium, or arsenic that leached from the wood. This study indicates that the benefits of incising can be obtained without the risk of increased leaching.

Some species, such as southern pine, are easily treated with preservatives, while others, like eastern and western hemlock, are considered to be more difficult to treat (refractory) or show wide variation in treatability. Even though refractory species are readily available in many areas and have adequate mechanical properties, the problem of treatability has somewhat limited their use in exterior applications (8). One solution is the use of mechanical incising to increase the amount of end grain that is exposed during treatment. During incising, the wood is forced between toothed rollers that cut many small slits parallel to the grain. Incising is widely used in the United States and Canada to improve the depth and uniformity of preservative treatment. American Wood Preservers' Association (AWPA) standards require incising for the treatment of sawn products from coastal Douglas-fir, Sitka spruce, hem-fir, eastern (northern) white pine, redwood, jack pine, lodgepole pine, alpine (subalpine) fir, eastern hemlock, western white spruce, and Englemann spruce (1).

Studies related to the incising and treatability of refractory wood species have focused on penetration and retention levels of the treated wood, or on the effects of incising on the mechanical properties, performance, stability, and surface appearance of the wood (2, 15-17, 20). The effect of incising on treatability of eastern and western hemlock lumber with waterborne preservatives has been examined (3-9, 12-14). Smith (19) reported that incising can substantially improve the treatment of eastern hemlock.

However, exposing additional wood surface for treatment and increasing preservative uptake can also cause increased leaching of preservative from the treated wood in service. Factors that can affect the rate of preservative release from treated wood are retention level, surface area, and grain orientation (IO). Although more uniform treatment can be achieved with incising, greater preservative loadings are also obtained. Greater preservative uptake and the larger surface area exposed by incising have the potential to increase preservative leaching. The objective of this study was to determine the relationship between leachability and incision density and depth.

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*Forest Products Society Member.

Forest Prod. J. 52(2):44-48.

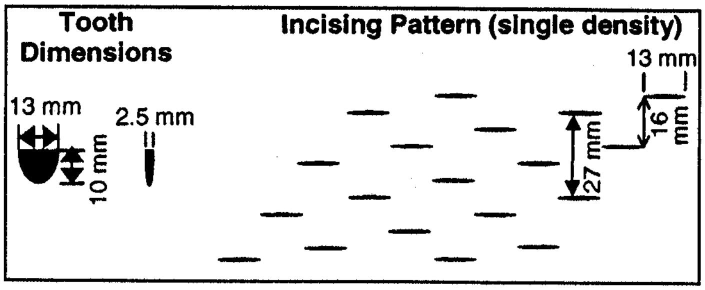

Figure 1. —Tooth dimensions and incising pattern.

MATERIALS AND METHODS

Ten freshly sawn eastern hemlock (*Tsuga canadensis* [L.] Carr.) flatsawn boards (3.05 m by 140 mm by 38 mm) containing both sapwood and heartwood were obtained from a mill in northern Wisconsin. The boards were stored at 2°C until cut into five 540-mm-long sections. Four sections from each board were incised using two incision density patterns (single or double: 2,750 or 5,500 incisions/m^2, respectively) and two incision depths (5 or 10 mm) **(Fig. 1).** Only the wide surfaces of the specimens were incised. The fifth section from each board was not incised and served as the control. After incising, specimens were conditioned to a moisture content of 10 to 12 percent in a room maintained at 23° ± 2°C and 65 percent ± 5% relative humidity before preservative treatment.

The end grain and unincised narrow faces were coated with two layers of neoprene rubber sealant to limit the penetration of preservative into these surfaces. The specimens were then weighed and pressure treated with 2 percent chromated copper arsenate type C (CCA-C) using a pressure cycle consisting of a 30-minute vacuum (-88 kPa gauge pressure) followed by a 2-hour pressure period (1,034 kPa gauge pressure). After treatment, the specimens were blotted dry and reweighed to determine preservative uptake. Net uptake retention was calculated by multiplying the total uptake by the concentration of the treating solution. The treated specimens were covered with a plastic wrap for 1 week to ensure CCA-C fixation to wood, then equilibrated to stable weight at 23° ± 2°C and 65% ± 5% relative humidity.

After conditioning, 1-cm-thick slices were cut from near each end and the middle of each specimen, and the freshly cut surfaces were sprayed with Chrome Azurol S indicator. A transparent plastic grid was placed over the exposed cross sections and the average amount of CCA-C penetration was measured as a percentage of the entire cross section. After determination of penetration, the slices were divided into three zones: 0 to 5 mm from the wood surface, 5 to 10 mm from the wood surface, and the core. For each slice, the wood in each zone was separately ground to pass a 40-mesh (420-µm) screen. The ground wood was then analyzed for chromium, copper, and arsenic content using an ASOMA x-ray fluorescence analyzer (XRF) (ASOMA Instruments, Austin, Texas). Results for the three assay slices cut from each section were averaged to obtain a single assay value for that section.

For the leaching trial, a shorter (190- by 140- by 38-mm) block was cut from each specimen. These blocks were end-coated with two layers of neoprene to minimize leaching from the end grain. Ten specimens from each treatment group were separately placed in individual plastic containers and submerged in 1500 mL of deionized water. All the leachates were removed and replaced with an equal amount of deionized water at intervals of 1, 2, 5, 10, 20, 30, and 60 days. The leachates were analyzed for chromium, copper, and arsenic with a Perkin Elmer 5100 PC atomic absorption spectrometer (AAS) using flame atomization for higher concentrations of the elements and graphite furnace atomization for lower concentrations. The percentage of elemental losses from each leaching specimen was calculated using preservative uptake or elemental assay of the entire cross section as the original retention.

The cumulative percentage of each leached chemical component, as determined by relative net uptake and assay retentions, was analyzed as a randomized complete block design structure and two-way factorial plus control treatment structure using SAS v6.12 proc MIXED (18). The comparisons were tested by single degree-of-freedom contrasts,

RESULTS AND DISCUSSION

RETENTION AND PENETRATION

As expected, incising improved the uptake of the treatment solution compared with the uptake in unincised samples **(Table 1).** Average retentions in samples incised to a depth of 10 mm appeared to be somewhat greater than average retentions in samples incised to only 5 mm. However, incision density (single vs. double) had little effect on net retention.

Incising had relatively little effect on the quantity of CCA components detected in the outer 5 mm of the samples, although a slight increase in retention apparently occurred **(Table 1).** However, incising doubled or tripled the amounts of copper, chromium, and arsenic found in the 5- to 10-mm assay zone. The greatest benefit was achieved by incising to a depth of 10 mm; doubling the number of incisions increased retention only slightly. Incising improved retentions in the core, although there was little difference between unincised samples and samples incised to a depth of 5 mm with the low density incising pattern.

All the incision patterns and depths greatly increased the percentage of the cross section penetrated with preservative **(Table 1).** As might be expected, the greatest penetration occurred in samples incised to the greater depth (10 mm). Doubling the number of incisions also appeared to increase penetration, especially in samples incised to a depth of only 5 mm. This finding agrees with that of Lebow and Morrell (11), who reported that the greatest benefit of increasing the incision density in Douglas-fir was improvement in the uniformity of penetration.

LEACHING

Incising appeared to have no effect on the amount of CCA leached from the samples, although the effect of the incisions is difficult to separate from the effect of the greater retention in the incised samples. On a percentage basis, the average amount of CCA leached from the incised samples was actually less than that from the unincised samples **(Table 2).** This difference is statisti-

TABLE 1. — Retention and penetration of CCA-C elements in incised and unincised eastern hemlock[a]

Incision		Average CCA-C uptake retention	Specimen	Retention by assay zone												Retention in cross section				CCA penetration
				0 to 5 mm				5 to 10 mm				Core								
Depth	Density			CrO_3	CuO	AS_2O_5	CCA	CrO_3	CuO	As_2O_5	CCA	CrO_3	CuO	As_2O_5	CCA	CrO_3	CuO	As_2O_5	CCA	
(mm)	(incisions/m^2)	(kg/m^3)		(%)																
			A	1.40	0.47	1.17		0.58	0.26	0.49		0.18	0.09	0.17		--	--	--		56.29
				(0.13)	(0.04)	(0.13)		(0.27)	(0.12)	(0.22)		(0.22)	(0.10)	(0.17)						(18.62)
5	2,750	7.79	B	1.37	0.44	1.16		0.58	0.25	0.48		0.24	0.11	0.21		--	--	--		62.22
		(1.91)		(0.17)	(0.05)	(0.13)		(0.21)	(0.10)	(0.18)		(0.20)	(0.09)	(0.17)						(17.24)
			C	1.40	0.47	1.19		0.66	0.29	0.56		0.29	0.14	0.25						63.43
				(0.16)	(0.05)	(0.13)		(0.25)	(0.11)	(0.23)		(0.23)	(0.11)	(0.19)		--	--	--		(20.29)
			Average	1.39	0.46	1.17	3.02	0.61	0.27	0.51	1.38	0.24	0.12	0.21	0.56	0.64	0.24	0.54	1.42	60.65
				(0.15)	(0.05)	(0.13)	(0.21)	(0.24)	(0.11)	(0.21)	(0.34)	(0.22)	(0.10)	(0.18)	(0.30)	(0.21)	(0.09)	(0.18)	(0.27)	(18.38)
			A	1.41	0.48	1.17		0.89	0.37	0.74		0.35	0.16	0.29						82.51
				(0.16)	(0.05)	(0.14)		(0.18)	(0.07)	(0.15)		(0.20)	(0.09)	(0.15)		--	--	--		(9.80)
10	2,750	9.83	B	1.39	0.48	1.18		0.90	0.37	0.74		0.31	0.15	0.27		--	--	--		82.10
		(1.12)		(0.19)	(0.07)	(0.16)		(0.18)	(0.08)	(0.15)		(0.16)	(0.07)	(0.12)						(6.89)
			C	1.41	0.47	1.21		0.94	0.39	0.78		0.38	0.17	0.32		--	--	--		84.89
				(0.13)	(0.05)	(0.11)		(0.17)	(0.08)	(0.15)		(0.20)	(0.09)	(0.15)						(5.98)
				1.40	0.48	1.19	3.07	0.91	0.38	0.75	2.04	0.34	0.16	0.29	0.80	0.77	0.30	0.65	1.72	83.16
			Average	(0.16)	(0.06)	(0.13)	(0.22)	(0.18)	(0.08)	(0.15)	(0.24)	(0.19)	(0.08)	(0.14)	(0.25)	(0.18)	(0.08)	(0.14)	(0.21)	(7.56)
			A	1.42	0.48	1.20		0.71	0.30	0.59		0.48	0.13	0.23		--	--	--		73.75
				(0.20)	(0.05)	(0.17)		(0.17)	(0.07)	(0.14)		(0.55)	(0.07)	(0.11)						(12.49)
5	5,500	8.21	B	1.41	0.47	1.21		0.69	0.30	0.58		0.24	0.11	0.20		--	--	--		69.65
		(1.40)		(0.11)	(0.04)	(0.09)		(0.17)	(0.07)	(0.14)		(0.13)	(0.06)	(0.10)						(11.76)
			C	1.40	0.47	1.21		0.70	0.30	0.58		0.34	0.15	0.28		--	--	--		70.89
				(0.15)	(0.06)	(0.12)		(0.22)	(0.09)	(0.19)		(0.22)	(0.11)	(0.17)						(15.51)
			Average	1.41	0.47	1.21	3.09	0.70	0.30	0.58	1.59	0.35	0.13	0.24	0.72	0.72	0.26	0.58	1.56	71.43
				(0.16)	(0.05)	(0.13)	(0.21)	(0.19)	(0.08)	(0.16)	(0.26)	(0.35)	(0.08)	(0.13)	(0.38)	(0.27)	(0.07)	(0.14)	(0.29)	(13.00)
			A	1.41	0.46	1.21		0.94	0.40	0.83		0.49	0.23	0.42		--	--	--		88.97
				(0.30)	(0.10)	(0.28)		(0.31)	(0.13)	(0.28)		(0.33)	(0.16)	(0.29)						(18.66)
10	5,500	10.31	B	1.52	0.50	1.32		1.00	0.42	0.86		0.45	0.21	0.39		--	--	--		90.02
		(1.86)		(0.13)	(0.04)	(0.12)		(0.20)	(0.08)	(0.17)		(0.28)	(0.14)	(0.23)						(10.12)
			C	1.55	0.50	1.34		1.02	0.42	0.86		0.40	0.18	0.35		--	--	--		87.08
				(0.15)	(0.05)	(0.16)		(0.16)	(0.06)	(0.15)		(0.15)	(0.10)	(0.17)						(7.32)
			Average	1.49	0.49	1.29	3.27	0.99	0.42	0.95	2.25	0.45	0.21	0.39	1.04	0.86	0.34	0.75	1.95	88.69
				(0.21)	(0.07)	(0.20)	(0.30)	(0.23)	(0.09)	(0.21)	(0.33)	(0.26)	(0.14)	(0.24)	(0.38)	(0.24)	(0.11)	(0.22)	(0.31)	(12.53)
			A	1.24	0.41	1.05		0.30	0.15	0.28		0.17	0.09	0.17		--	--	--		36.86
				(0.21)	(0.07)	(0.21)		(0.10)	(0.05)	(0.08)		(0.10)	(0.05)	(0.08)						(10.07)
--	Unincised	5.20	B	1.27	0.39	1.07		0.36	0.17	0.28		0.15	0.07	0.15		--	--	--		35.49
		(1.00)		(0.24)	(0.07)	(0.22)		(0.12)	(0.05)	(0.12)		(0.18)	(0.08)	(0.14)						(11.37)
			C	1.28	0.40	1.09		0.32	0.15	0.29		0.25	0.10	0.21		--	--	--		39.08
				(0.20)	(0.06)	(0.22)		(0.16)	(0.07)	(0.13)		(0.13)	(0.05)	(0.10)						(12.49)
			Average	1.26	0.40	1.07	2.74	0.33	0.16	0.28	0.77	0.19	0.09	0.18	0.45	0.51	0.19	0.44	1.14	37.14
				(0.22)	(0.07)	(0.21)	(0.31)	(0.13)	(0.06)	(0.11)	(0.18)	(0.14)	(0.06)	(0.11)	(0.19)	(0.16)	(0.06)	(0.15)	(0.16)	(11.06)

[a] Numbers in parentheses are standard deviations.

TABLE 2. — Cumulative leached CCA-C elements from incised and unincised eastern hemlock after 60 days.[a]

Incision		Average CCA-C uptake retention	Cumulative leached elements based on AAS			Cumulative percentage of leaching							
						Based on assay retention[b]				Based on uptake retention			
Depth	Density		CrO_3	CuO	As_2O_5	CrO_3	CuO	As_2O_5	CCA-C	CrO_3	CuO	As_2O_5	CCA-C
(mm)	(incisions/m^2)	(kg/m^3)	(mg)			(%)							
5	2,750	7.79 (1.91)	9.18 (3.13)	2.06 (0.34)	12.78 (1.01)	0.43 (0.30)	0.24 (0.12)	0.71 (0.25)	0.50 (0.26)	0.31 (0.24)	0.18 (0.10)	0.57 (0.21)	0.39 (0.21)
10	2,750	9.83 (1.12)	6.16 (1.03)	2.03 (0.50)	12.01 (1.04)	0.23 (0.14)	0.19 (0.09)	0.53 (0.18)	0.34 (0.15)	0.16 (0.09)	0.14 (0.05)	0.40 (0.12)	0.24 (0.10)
5	5,500	8.21 (1.40)	6.19 (1.03)	1.96 (0.20)	12.00 (0.94)	0.26 (0.18)	0.21 (0.07)	0.62 (0.19)	0.39 (0.17)	0.20 (0.13)	0.17 (0.06)	0.51 (0.16)	0.31 (0.13)
10	5,500	10.31 (1.86)	7.06 (0.93)	2.62 (0.25)	14.77 (1.20)	0.25 (0.12)	0.23 (0.09)	0.60 (0.23)	0.38 (0.17)	0.18 (0.08)	0.17 (0.06)	0.49 (0.17)	0.29 (0.12)
- -	Unincised	5.20 (1.00)	5.63 (1.02)	1.76 (0.35)	10.73 (1.29)	0.34 (0.21)	0.29 (0.22)	0.75 (0.42)	0.48 (0.31)	0.29 (0.17)	0.24 (0.17)	0.72 (0.38)	0.43 (0.26)

[a] Numbers in parentheses are standard deviations.

[b] Assay of quantity of CCA component in entire cross section.

TABLE 3. — Probability of statistical differences in percentage of leached CCA components as a function of incising density and depth.[a]

	Probability based on assay retention			Probability based on uptake retention		
Comparison	CuO	CrO_3	As_2O_5	CuO	CrO_3	As_2O_5
Unincised vs. incised	0.1202	0.3827	0.0637	0.0172	0.071	0.0006
Density, double vs. single	0.8615	0.095	0.828	0.6978	0.2104	0.7881
Depth, 5 vs. 10 mm	0.6345	0.0288	0.1177	0.5595	0.0221	0.0875
Density vs. depth	0.2868	0.0429	0.212	0.2951	0.0801	0.1889

[a] The p-value associated with a comparison is the probability of obtaining a test statistic of at least its observed magnitude given that the linear combination of effects identified by the contrast is not different from zero. A small p-value (less than 0.05) indicates that there is sufficient evidence to declare a significant difference.

cally significant for copper and arsenic when leaching is based on uptake retention, but it is not significant based on assay retention **(Table 3).** It is likely that the appearance of greater leaching from the unincised samples is an effect of their lower original retention. Previous studies have suggested that leaching does not increase in direct proportion to retention (10). Similarly, the percentage of chromium leached from the samples incised to a depth of 5 mm was significantly greater than that for the samples incised to a depth of 10 mm **(Table 3).** This effect is probably also a function of the lower retention in the samples incised to a depth of only 5 mm. On an absolute basis, the amount of arsenic released from the incised samples appeared greater than that released from the unincised samples **(Table 2).** However, as with total CCA, this trend was reversed when leaching was considered on a percentage basis. Even when leaching was considered on an absolute basis, releases of copper and chromium were only slightly higher from incised than unincised samples, despite the differences in retention.

The lack of difference in leaching rates at the higher retentions may be more understandable if one considers the relatively little difference in retention in the outer 5 mm of the samples **(Table 1).** Components in the outer shell are most available during the early stages of leaching, when most losses occur **(Fig. 2).** Higher retentions in incised samples might result in increased leaching over the very long term, but such differences are likely to be of little practical significance. The 30- and 60-day leaching data from our study indicate that leaching from all the treatment groups stabilized at very low release rates.

It is interesting to note that the rate of chromium release was greater than that of copper for all treatment groups. In most previous studies, the opposite result was reported (10). This may be an effect of the wood species used.

CONCLUSIONS

Incising greatly increased the penetration and inner assay zone retention of CCA-C in eastern hemlock. The improvement in the uniformity of penetration was particularly notable. Incising was not associated with increased leaching of CCA from the wood. Although this study evaluated only one wood species and preservative combination, it appears that the benefits of increased retention and penetration derived from incising can be obtained without the risk of increased leaching.

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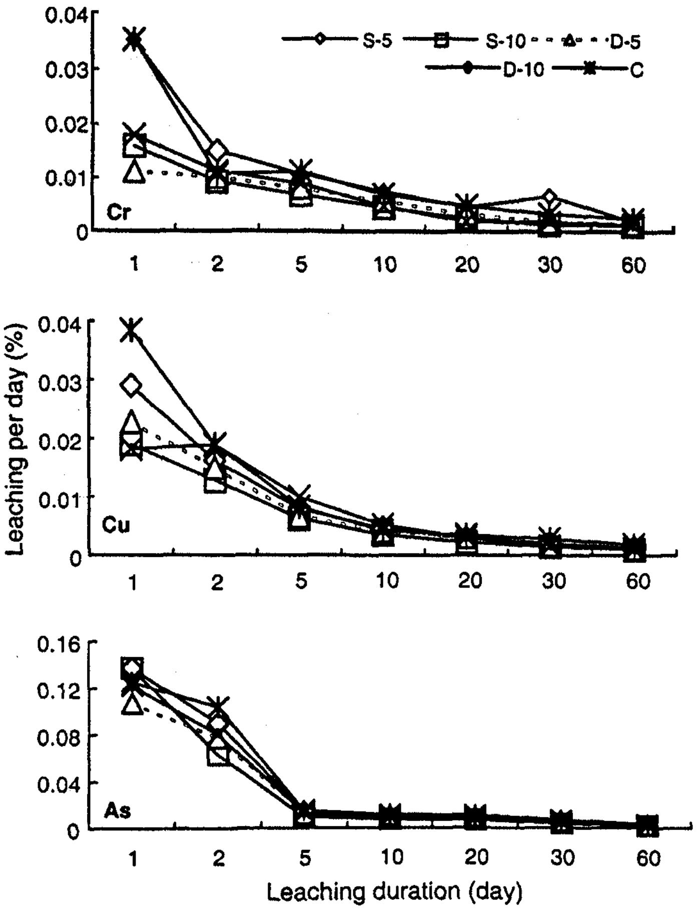

Figure **2.**— Percentage of leaching per day of chromium, copper, and arsenic from incised and unincised eastern hemlock, based on uptake retention.

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