EFFECTS OF LEAN IN RED ALDER TREES ON WOOD SHRINKAGE AND DENSITY

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ABSTRACT

Certain wood qualities may be affected by lean in red alder (*Alnus rubra* Bong.) trees. Such characteristics as shrinkage and density can potentially cause problems in the manufacture of products from red alder. Thirty-six trees with varying degrees of lean (0 to 20 degrees) and different diameters (12 to 24 inches) were selected. Cross-sectional disks were cut from the top of the first 10-foot log and used for measuring shrinkage (longitudinal, radial, and tangential) and density. Wood density was measured using an X-ray densitometer. Each sample was categorized as coming from the tension or compression side of the stem. Subsampling within sides permitted examination of the effect on shrinkage of position in relation to the pith. Longitudinal, radial, and tangential shrinkages were affected by all or some of the following factors: lean, side, and position. There was no significant effect of lean or side on wood density.

Keywords: Red alder, shrinkage, X-ray densitometry.

INTRODUCTION

Red alder (*Alnus rubra* Bong.) is the predominant hardwood species in the Pacific Northwest. Although the available volume of this resource has been increasing over the years, utilization has not increased proportionately. Two to four times as much alder currently is being grown as is being harvested (Plank et al. 1990). This fast-growing species can yield two to three rotations in the time needed for one softwood rotation, and the nitrogen-fixing capability of alder (Tarrant 1977) increases site productivity for other species.

Furniture, cabinets, pallets, pulp, and specialty products are the main items manufactured from red alder. As log diameter increases, the amount of clear lumber produced increases and lumber value rises. There is little difference in log value between red alder and Douglas-fir on the basis of dollars per hundred cubic feet (Plank et al. 1990). The value from primary log processing increased by $21 million from 1977 to 1985 (Beachy and McMahon 1987). Resch (1988) reports that employment from secondary manufacturing operations is about 6.4 times more, and payroll 5.8 times higher, than from sawmills.

Although there is limited information on wood quality properties of alder, one growth characteristic of concern is its tendency to lean. Hardwood species may respond to lean with eccentric growth and tension wood. Tension wood often has a higher density and greater longitudinal shrinkage than normal wood. Le-

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ney et al. (1978) found that alder lacks well-developed tension wood. Harrington and DeBell (1980) found that provenance, site, and age have little effect on variation of wood density. Parker et al. (1978) studied density and ring width patterns in a small number of trees by using X-ray densitometry; no consistent trend in wood density was observed. Willits et al. (1990) determined that there is no loss in lumber volume or value as a result of lean.

This study examined the effect of lean in red alder trees on two wood quality characteristics—shrinkage and density—that can affect processing and utilization. The objectives were: (1) to measure longitudinal, radial, and tangential shrinkage and wood density; (2) to compare shrinkage among lean classes, between tension and compression sides of the stem, and between inner and outer wood (position from the pith), and to test for interactions among these factors; and (3) to compare density among lean classes and between tension and compression sides and to test for interactions between these factors.

MATERIALS AND METHODS

Thirty-six red alder trees were selected from a larger sample taken from six areas in the Coast Range of northwestern Oregon that originally were used for product recovery, volume, and value studies (Plank et al. 1990; Willits et al. 1990). Lean was measured at about 6 feet above ground level and represented the degree of deviation from vertical. Trees were assigned to one of three lean classes with each class having 12 trees: lean class 1 (less than 4 degrees), lean class 2 (6 to 12 degrees), and lean class 3 (greater than 15 degrees). Cross-sectional disks were cut from the top of the first 10-foot log for shrinkage and wood density studies. The presence (or absence) of tension wood in these samples was not determined.

Shrinkage

Radial strips 4 to 5 inches along the grain and aligned with the lean were sawn from the disks. For all trees, regardless of the degree of lean, the shorter radius was designated the compression side and the opposite side labeled the tension side. Each strip was cut into segments about 1.9 cm (¾ in.) in both the radial and tangential directions. The first three segments closest to the pith on both the tension and compression sides were designated inner wood. The remaining segments (outward to the bark) were labeled outer wood. The inner three segments would be representative of boards that were processed from the center of the tree. Shrinkage values were calculated by using green and oven-dry dimensions measured with digital calipers. Longitudinal, radial, and tangential shrinkages were measured from pith to bark on the tension and compression sides for inner and outer wood.

The experimental design was a split-split plot. Trees (whole plot) were classified into three lean classes. Side, tension or compression, was the split-plot. Position within each side, inner and outer wood, was the split-split plot. Analysis of variance (ANOVA) was used to test for differences in shrinkage (longitudinal, radial, tangential, and ratio of tangential to radial) among lean class, between sides, between positions, and to test for interactions among these factors. An alpha-level of 0.05 was chosen for declaring statistically significant differences in means. Subsampling frequency was different because tension and compression side radii differed, and samples containing knots and splits were not included.

Wood density

Radial strips 1.5 mm thick were sawn across the diameter of the sample in the direction of lean. They were cut at the pith and assigned tension and compression sides based on length. Because Kurth and Becker (1953) found red alder wood to have an extractive content of 8.6%, and extractive content can influence X-ray densitometer results, samples were extracted before processing (extraction procedure followed ASTM D 1105-84; toluene was substituted for benzene). Samples were allowed to come to room conditions (equilibrium moisture content about 9%). Wood density profiles were generated by using a direct scan-

TABLE 1. *Mean longitudinal shrinkage in leaning red alder trees.*

Side	Position	Lean <4°	Lean 6°–12°	Lean >15°	Lean Combined
		percent			
Tension	Inner	0.27 (0.0172)[a]	0.27 (0.0233)	0.40 (0.0504)	0.31 (0.0214)
	Outer	0.29 (0.0288)	0.27 (0.0148)	0.49 (0.0522)	0.35 (0.0260)
	Combined[b]	0.28 (0.0169)	0.27 (0.0132)	0.45 (0.0370)	0.33 (0.0170)
Compression	Inner	0.26 (0.0213)	0.23 (0.0244)	0.24 (0.0424)	0.25 (0.0176)
	Outer	0.25 (0.0138)	0.24 (0.0197)	0.23 (0.0337)	0.24 (0.0135)
	Combined	0.26 (0.0124)	0.24 (0.0152)	0.24 (0.0265)	0.24 (0.0109)
Combined[c]	Inner	0.27 (0.0136)	0.25 (0.0171)	0.32 (0.0358)	0.28 (0.0143)
	Outer	0.27 (0.0161)	0.26 (0.0124)	0.36 (0.0405)	0.30 (0.0159)

[a] Numbers in parentheses are standard errors of the mean.
[b] Inner and outer wood combined.
[c] Tension and compression sides combined.

ning X-ray densitometer. Alder is a diffuse-porous wood, and position of the scan line could influence density readings. Each sample therefore was scanned twice, and an average density was calculated. X-ray density values were adjusted to oven-dry weight/green volume condition by using ASTM standard D 2395 (ASTM 1991).

The experimental design was a split plot. Trees (whole plot) were classified into three lean classes. Side, tension or compression was the split-plot. The ANOVA was used to test for differences in density among lean classes, between tension and compression sides, and for interactions between these factors.

RESULTS AND DISCUSSION

Shrinkage

Longitudinal shrinkage means are shown in Table 1. Values ranged from 0.23 to 0.49%. The tension side had greater longitudinal shrinkage than the compression side in all three lean classes, with the greatest difference found in trees leaning more than 15 degrees.

The ANOVA summary (Table 2) shows a marginally significant three-way interaction among lean class, tension-compression side, and inner-outer wood ($P = 0.07$) for longitudinal shrinkage. The interaction between lean class and tension-compression side was highly significant ($P = 0.01$). This two-way interaction is shown in Fig. 1.

It is estimated that tension wood has about five times more longitudinal shrinkage than normal wood (U.S. Department of Agriculture 1987); however, this magnitude of difference was not found in any of the trees with lean. Excessive longitudinal shrinkage will cause warp. The study by Willits et al. (1990) found a statistically significant relation between lean in trees and both crook and bow in lumber;

TABLE 2. *Analysis of variance results for shrinkage.*

Source	df	Longitudinal F-value	Longitudinal Pr > F	Radial F-value	Radial Pr > F	Tangential F-value	Tangential Pr > F
Lean	2	5.26	0.0104	1.37	0.2683	1.41	0.2593
Tension or compression side	1	13.79	0.0008	6.16	0.0183	9.96	0.0034
Inner or outer wood	1	49.89	0.1030	0.19	0.6629	43.25	0.0001
T/C side•I/O wood	1	19.09	0.0852	1.87	0.1765	0.22	0.6411
Lean•T/C side	2	5.28	0.0103	2.53	0.0952	7.47	0.0021
Lean•I/O wood	2	1.87	0.1620	2.95	0.0598	2.16	0.1234
Lean•T/C side•I/O wood	2	2.80	0.0684	1.70	0.1918	2.22	0.1174

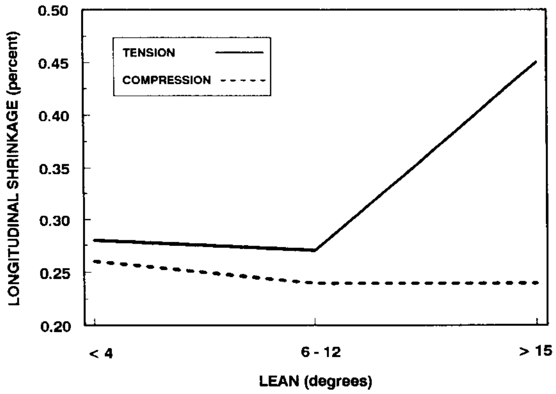

FIG. 1. Response of longitudinal shrinkage to lean class and tension or compression side.

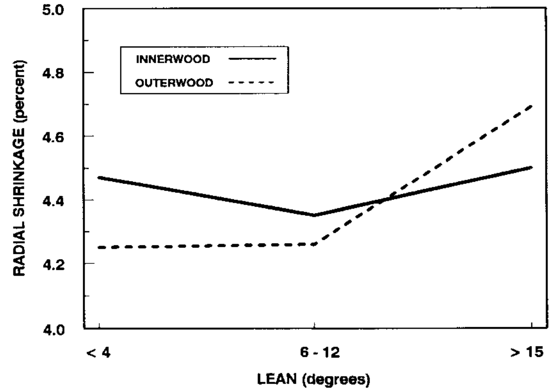

FIG. 2. Response of radial shrinkage to lean class and position (inner or outer wood).

but neither was of practical significance when the end product was taken into consideration.

Table 3 shows radial shrinkage means from this study; from 4.18% (lean greater than 15 degrees, compression side, inner wood) to 4.85% (lean greater than 15 degrees, tension side, outer wood). The Wood Handbook (U.S. Department of Agriculture 1987) lists 4.4% as the average radial shrinkage for red alder.

A marginally significant interaction ($P = 0.06$) was found between lean class and position, inner and outer wood (Table 2; Fig. 2). The radial shrinkage in outer wood is roughly equal for the first and second lean class and increases for lean class 3. The ratio of shrinkages between lean classes 2 and 3 is about 1.1, from 4.26 to 4.69%.

Radial shrinkage differed significantly ($P = 0.02$) between the tension and compression sides. The mean radial shrinkage on the tension side is 4.51% and on the compression side is 4.34%. The ratio of tension-to-compression side shrinkages is slightly less than 1.04 and not likely to be of practical significance.

Tangential shrinkage means (Table 4) ranged from 6.67% (lean 6 to 12 degrees, compression side, outer wood) to 8.32% (lean greater than 15 degrees, tension side, inner wood). Some tangential shrinkages obtained in this study were slightly higher than the 7.3% reported in the Wood Handbook (U.S. Department of Agriculture 1987).

Results from the ANOVA (Table 2) for tangential shrinkage indicated a highly significant

TABLE 3. *Mean radial shrinkage in leaning red alder trees.*

Side	Position	Lean <4°	6°–12°	>15°	Combined
		percent			
Tension	Inner	4.63 (0.2216)[a]	4.29 (0.1640)	4.85 (0.1906)	4.59 (0.1154)
	Outer	4.27 (0.1356)	4.29 (0.1557)	4.73 (0.2474)	4.43 (0.0894)
	Combined[b]	4.44 (0.1301)	4.29 (0.1103)	4.78 (0.1171)	4.51 (0.0724)
Compression	Inner	4.32 (0.1177)	4.41 (0.1956)	4.18 (0.1963)	4.30 (0.0980)
	Outer	4.22 (0.1167)	4.24 (0.1626)	4.66 (0.1695)	4.37 (0.0917)
	Combined	4.27 (0.0817)	4.32 (0.1247)	4.42 (0.1363)	4.34 (0.0667)
Combined[c]	Inner	4.47 (0.1240)	4.35 (0.1252)	4.50 (0.1513)	4.44 (0.0768)
	Outer	4.25 (0.0877)	4.26 (0.1102)	4.69 (0.1100)	4.40 (0.0637)

[a] Numbers in parentheses are standard errors of the mean.
[b] Inner and outer wood combined.
[c] Tension and compression sides combined.

TABLE 4. *Mean tangential shrinkage in leaning red alder trees.*

Side	Position	Lean <4°	6°–12°	>15°	Combined
		percent			
Tension	Inner	7.41 (0.2361)[a]	8.16 (0.1358)	8.32 (0.2524)	7.96 (0.1391)
	Outer	7.25 (0.1250)	7.21 (0.0839)	7.69 (0.1810)	7.38 (0.0845)
	Combined[b]	7.33 (0.1284)	7.66 (0.1274)	7.99 (0.1642)	7.66 (0.0867)
Compression	Inner	7.94 (0.1836)	7.71 (0.2117)	7.55 (0.2747)	7.73 (0.1306)
	Outer	7.18 (0.1467)	6.67 (0.2624)	7.23 (0.1326)	7.02 (0.1148)
	Combined	7.56 (0.1399)	7.17 (0.2005)	7.39 (0.1527)	7.37 (0.0960)
Combined[c]	Inner	7.69 (0.1553)	7.94 (0.1326)	7.92 (0.2009)	7.84 (0.0956)
	Outer	7.21 (0.0946)	6.94 (0.1462)	7.46 (0.1195)	7.20 (0.0739)

[a] Numbers in parentheses are standard errors of the mean.
[b] Inner and outer wood combined.
[c] Tension and compression sides combined.

interaction ($P < 0.01$) between lean class and tension vs. compression side (Fig. 3). On the tension side, the tangential shrinkage increased with increasing lean.

Position (inner or outer wood) significantly affected tangential shrinkage ($P < 0.01$). Inner wood had a mean shrinkage of 7.84%, and the outer wood value was 7.20%. For all lean classes, inner wood shrinkage was greater than outer wood shrinkage.

The ratio of tangential to radial shrinkage provides information on the dimensional stability of wood. A low ratio is important where dimensional stability is required (Panshin and deZeeuw 1970). Worthington et al. (1962) state that because of the moderate differences between radial and tangential shrinkage, red alder is an easy wood to dry. This study found a highly significant difference ($P < 0.01$) between the ratio in the inner wood (mean ratio = 1.84) and that of the outer wood (mean ratio = 1.68). The inner wood represents the center cant that is usually left whole when red alder is sawed. These cants are manufactured into products, such as pallet stock, where stability generally is not important. Thus, even though there was a significant difference between inner and outer wood in this study, that difference may not lower volume or value recovery from a log.

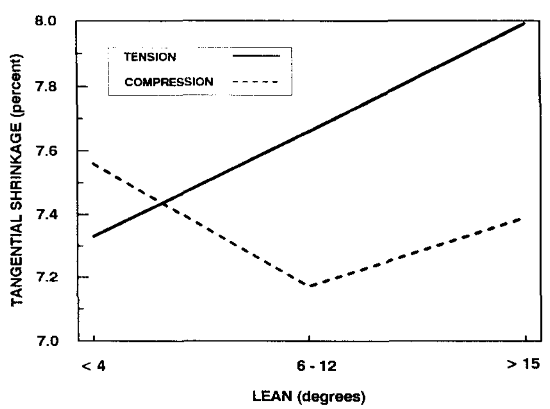

FIG. 3. Response of tangential shrinkage to lean class and tension or compression side.

Density

Table 5 summarizes density means. Mean of all samples was 0.41 (adjusted to oven-dry weight, green volume). An analysis of variance indicated that density was not significantly dif-

TABLE 5. *Summary of X-ray density values adjusted to oven-dry weight and green volume.*

Lean (degree)	Side	Mean (g/cm^3)	Range (g/cm^3)	Standard error
<4	Tension	0.40	0.36–0.46	0.0069
	Compression	0.40	0.35–0.43	0.0061
6–12	Tension	0.41	0.35–0.45	0.0074
	Compression	0.41	0.36–0.45	0.0069
>15	Tension	0.42	0.38–0.50	0.0088
	Compression	0.41	0.39–0.47	0.0064

ferent among trees from different lean classes or within each tree based on tension vs. compression side. What was evident from the analysis was that much variation exists in density among trees within each lean class.

SUMMARY AND CONCLUSIONS

Longitudinal shrinkage was affected by lean, side (tension or compression), and position (inner or outer). The tension side had more longitudinal shrinkage than the compression side. This effect was most obvious for lean class 3 (trees with lean greater than 15 degrees) where the shrinkage of the tension side was almost twice that of the compression side. The magnitude of difference was not enough to suspect the presence of tension wood.

A statistical interaction between lean class and position was found for radial shrinkage. The largest amount of radial shrinkage occurred in those trees with lean greater than 15 degrees. Although radial shrinkage was significantly different between the tension side and the compression side, the difference (0.17%) probably holds no practical significance.

There was a significant interaction between lean class and side (tension or compression) for tangential shrinkage. Shrinkage increased as lean increased on the tension side. No consistent trend in shrinkage was noted on the compression side. Tangential shrinkage differed significantly by position (inner or outer wood). The ratio of inner wood tangential shrinkage to that of the outer wood was about 1.09.

The ratio of tangential to radial shrinkage is higher in the inner wood than in the outer wood, which indicates that the inner wood would tend to be less dimensionally stable than the outer wood.

Lean had no effect on density among trees from different lean classes or within each tree when comparing tension and compression sides.

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