TECHNICAL NOTE: SHRINKAGE PROPERTIES OF PARTIALLY CAD-DEFICIENT LOBLOLLY PINE LUMBER

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Abstract. Partially cinnamyl alcohol dehydrogenase-deficient and wild-type loblolly pine (*Pinus taeda*) were studied for shrinkage properties. The study established no significant difference between these two genotypes. Results also showed that shrinkage of juvenile wood is significantly different from the corresponding shrinkage of mature wood only in the radial direction. Tangential shrinkage difference between juvenile and mature wood was significant when the uncorrected values were used but not when the true shrinkage values were used, thus highlighting the need to account for the effect of growth ring curvature on tangential shrinkage measurement of small-diameter trees.

One of the best performing first-generation parents of genetically improved loblolly pine (*Pinus taeda*) is Plus-tree 7-56. This line is also the only known natural carrier of a mutant gene, the cad-n1 allele, which codes for deficiency in cinnamyl alcohol dehydrogenase (CAD). The incidence of the cad-n1 allele is manipulated in breeding work to produce two types of mutant trees: totally and partially CAD-deficient. The properties of totally CAD-deficient pine have been extensively studied, but work on the properties of partially CAD-deficient pine is limited and is largely related to paper manufacture. We have initiated a series of investigations to assess the impact of partial CAD deficiency on properties related to solid wood and structural wood-based composites applications. A paper on the mechanical properties of partially CAD-deficient loblolly pine is published elsewhere (Saralde et al 2008). This article deals with the shrinkage characteristics of the material.

The specimens used in this study were obtained from the same logs described in Saralde et al (2008). For transverse shrinkage measurements, two cross-sectional discs, each 25 mm thick, were cut from each log. A pie-shaped section was cut from one of the discs as shown in Fig 1a. Removal of the left and right corners of the pie presented parallel surfaces for measurement of the tangential dimension of the mature wood T_m. The center point of the virtual rectangle (shaded area) was marked and the distance, r_m, from this point to the pith was measured. The pie was then cut at the 10th growth ring from the pith to separate mature from juvenile wood. The

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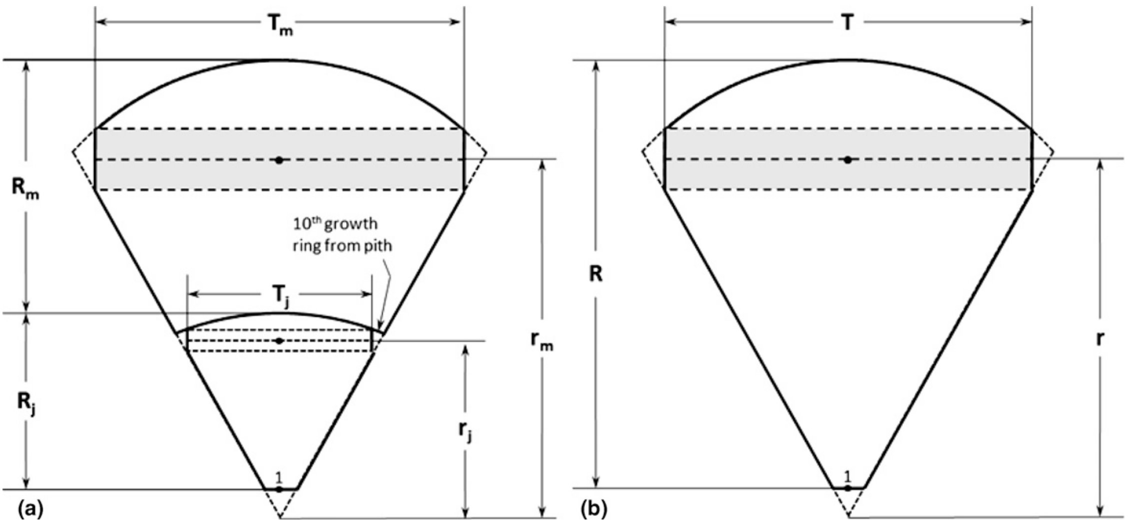

Figure 1. Diagram of pie-shaped samples for radial and tangential shrinkage measurements: (a) separate juvenile and mature wood shrinkages and (b) whole wood shrinkage.

radial dimension of the mature wood, R_m, was then measured. The pie-shaped juvenile wood was cut in the same manner as described previously to allow for the measurement of T_j, r_j, and R_j. A pie-shaped section was also cut from the second disc to end-match the section obtained from the first disc. This material allowed for the measurement of T, r, R that went toward the calculation of the T and R shrinkages of the whole wood (Fig 1b). For longitudinal shrinkage, the green dimensions L_j and L_m were measured on 38- (radial) × 38- (tangential) × 100-mm (longitudinal) samples obtained from the juvenile and mature wood portions of each log. After measuring the oven-dry dimensions (T_o, R_o, and L_o), percentage shrinkage values in the three directions were calculated using the general shrinkage formula. To correct for growth ring curvature, the measured T shrinkage was converted to the true percentage tangential shrinkage using the equation from Kelsey and Kingston (1953). A linear model for a two-way analysis of variance (ANOVA) was used to test the effect of genotype (wild-type vs partially CAD-deficient) and wood type (juvenile vs mature) on the percentage shrinkage in the different directions. The computed values for R, T, and L shrinkage for the different genotypes and wood types are presented

Table 1. *Average percent shrinkage for the juvenile wood, mature wood, and whole wood portions of wild-type (WT) and partially cinnamyl alcohol dehydrogenase-deficient (CAD) loblolly pine in the R, T, and L directions.*[a]

	Radial		Tangential		Longitudinal	
	WT	CAD	WT	CAD	WT	CAD
Juvenile wood	4.14 (12.5)	4.04 (13.0)	7.41 (10.3)	7.32 (13.4)	0.18 (64.6)	0.35 (97.1)
Mature wood	6.49 (11.9)	6.70 (13.1)	7.54 (9.6)	8.02 (14.0)	0.15 (54.1)	0.17 (76.2)
Whole wood	4.87 (11.4)	4.81 (10.2)	7.83 (7.3)	7.85 (11.4)	—	—

[a] Numbers in parentheses are the percent coefficients of variation.

in Table 1. Because the ANOVA showed that the interaction effect between the genotype and wood type is not significant, the two main factors are discussed separately subsequently.

The shrinkage of partially CAD-deficient pine was not significantly different from that of wild-type pine in the R, T, and L directions. The results here support the findings in the earlier paper (Saralde et al 2008) in which it was also shown that partially CAD-deficient pine was not significantly different from the wild-type in terms of mechanical properties. The R (4.8%) and T (7.4%) shrinkage values reported in the Wood Handbook (Forest Products Laboratory 1999) for loblolly pine are in-between those obtained in this study for juvenile and mature wood and are comparable to those for whole wood. The average L shrinkage values in Table 1 are also close to reported values (0.1 – 0.3%), but we feel less confident with our results because of the large coefficients of variation.

Previous investigators have observed that juvenile wood shrinks more longitudinally than mature wood, whereas the opposite is true in the R and T directions. As shown in Table 1, the L shrinkage values of juvenile wood are greater than those for the mature wood but because of the large coefficients of variation, the ANOVA was not significant. In the transverse direction, juvenile wood has a distinctly lower shrinkage value than mature wood in only the R direction ($p < 0.0001$). The value for whole wood is in between those of juvenile and mature wood.

The T-shrinkage results are different from those of many researchers who observed that T shrinkage of juvenile wood is less than that for mature wood. This discrepancy must be because of the ring curvature adjustment performed in this study. In fact, if the measured T shrinkage values were used in the analysis, the ANOVA would have shown a statistically significant difference between juvenile and mature wood shrinkage with a p value of 0.048. Like the Kelsey and Kingston (1953) equation shows, the difference between the true and measured T shrinkage is dependent on 2r/T, which must be large enough to reduce the error in T shrinkage measurement. For this study, a 2r/T value of at least 4 was maintained, thereby limiting the error to less than 0.2%. The quantity 2r/T can be maximized by maximizing the value of r. This is the situation when logs are large and a tangential cut near the bark produces a flatsawn board with growth rings that are nearly flat. This is what is assumed in the work of other researchers who did not consider growth ring curvature. For small-diameter trees or for samples cut near the pith, the radius of curvature is small and therefore the error in T shrinkage measurement is greater. One approach to dealing with small-diameter logs is to decrease the T dimension of the sample. The drawback of this approach is that the measurement of small dimensions requires high-precision tools. The Kelsey and Kingston equation also highlights the advantage of using a pie-shaped sample over prismatic parallelepiped samples. With a pie-shaped sample, the value of 2r/T remains more or less constant irrespective of radial location; therefore, the error is also constant. Thus, for our measurement of T shrinkage, the 2r/T of the mature wood was equal to that of the juvenile wood, thereby making the comparison between these two wood types valid.

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