Southwest Great Plains

Research Note RM-492

September 1989

USDA Forest Service

Rocky Mountain Forest and Range Experiment Station

Fibril Angle in Young-Growth Ponderosa Pine as Related to Site Index, D.B.H., and Location in Tree

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Young-growth ponderosa pine on two different sites in northern New Mexico were evaluated for differences in fibril angle. Measurements were made radially at the butt end, mid-length, and top end of the merchantable stem divided into multiple 8-foot log lengths. Results indicated that the butt ends have larger fibril angles than the other two locations. Fibril angle did not vary significantly with either site index from 55 to 100 or d.b.h. from 9 to 14 inches.

Keywords: Ponderosa pine, fibril angle, young growth, site index

Management Implications

Loss of lumber grade from excessive warp usually results from abnormal and/or asymmetrical shrinkage when lumber dries. In conifers, fibril angle, juvenile wood, compression wood, grain orientation, and knots have been associated with excessive lumber warpage. Longitudinal shrinkage typically ranges from 0.1% to 0.3% when wood is dried from green to ovendry conditions. Longitudinal shrinkage greater than 0.3% from green to overdry conditions for straight grain material is considered abnormal and is related to deviation of the microfibrils (fibril angle) from the longitudinal axis of the tracheid. Study results indicated that the fibril angle of young-growth ponderosa pine did not significantly vary with site index from 55 to 100 or d.b.h. from 9 to 14 inches.

Introduction

Fibril angle of the S_2 layer of woody cells has been shown to affect some properties of wood material (McMillin 1973, Meylan 1972, Panshin and de Zeeuw 1980, Piirto et al. 1974, Voorhies and Blake 1981, Voorhies and Groman 1982). Variations in shrinkage and mechanical behavior have been the properties of primary interest. The researchers cited generally agreed on two aspects of fibril angle: (1) large fibril angles (as measured from the longitudinal axis) in softwood tracheids and hardwood fibers result in reduced mechanical properties parallel to the grain and in increased longitudinal shrinkage; (2) fibril angle is inversely related both to distance from the pith and to cell length, with regions of a tree undergoing rapid growth (i.e., earlywood, juvenile wood, reaction wood) generally having larger fibril angles than regions growing more slowly. The increased longitudinal shrinkage associated with larger fibril angles often results in warp, specifically crook and bow, when there is a marked asymmetric distribution of fibril angles throughout a piece of lumber.

This fibril angle study was part of a larger project investigating the development of warp during drying in young-growth ponderosa pine from the southwestern United States (Markstrom et al. 1984). Significant results of that study were that lumber grade recovery and warp were related primarily to tree and log diameters, and the factor of height location in the tree had no effect on the amount of warp that developed. The objective of this research was to develop an equation that would predict fibril angle in young-growth ponderosa pine (*Pinus*

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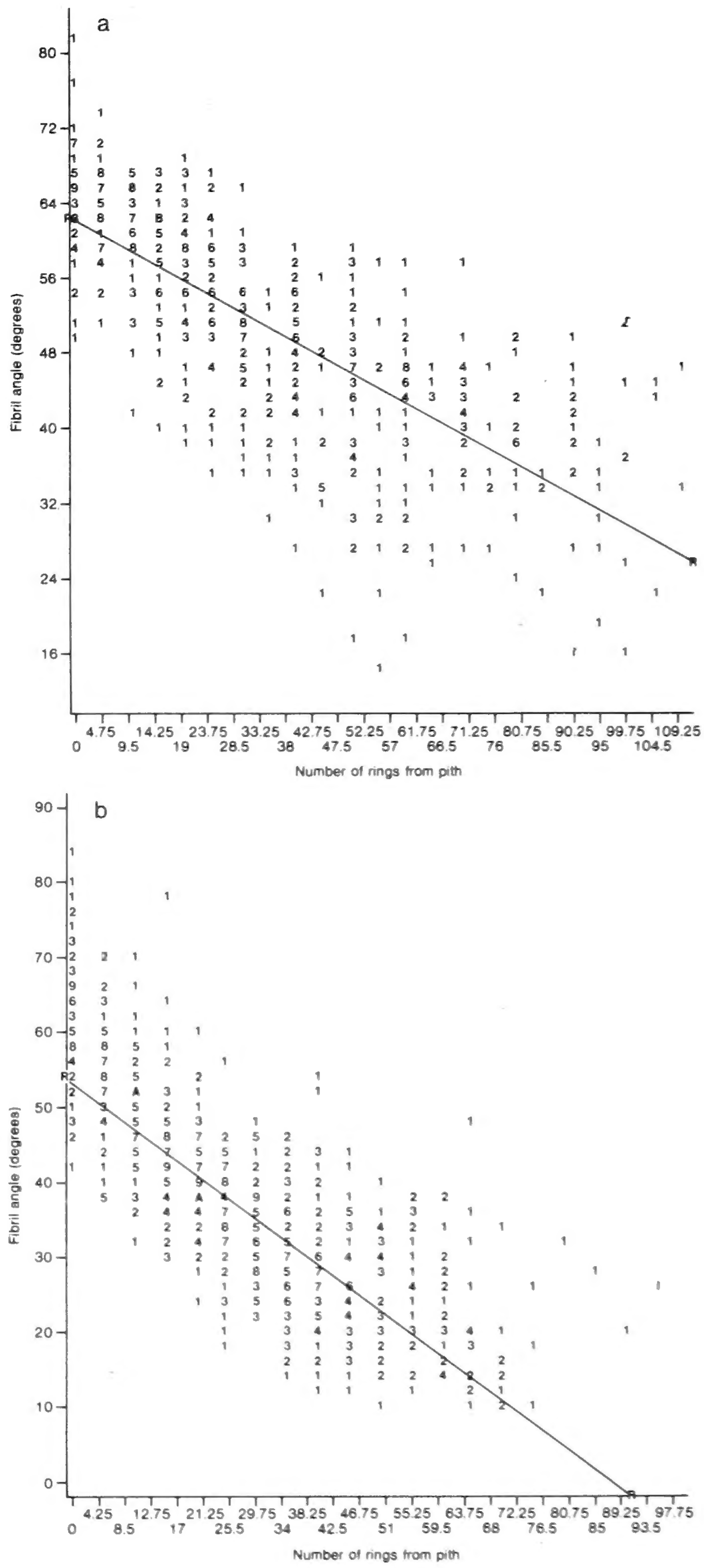
ponderosa Dougl. ex Laws) using the variables of site index, diameter at breast height (d.b.h.), relative height location in the tree, and distance from the pith.



Methods

Forty-one trees ranging from 9 to 14 inches d.b.h. were cut from an area with a site index of 55. Another 41 trees with the same diameter range were cut from an area with a site index of 100. Both sites were located in the Santa Fe National Forest in northern New Mexico. Studs cut from these trees were used for the earlier drying study (Markstrom et al. 1984).

Sixty of the trees (5 for each of the 6 d.b.h. classes on each site) were sampled for fibril angle. When the trees were felled, a 1/2-inch-diameter increment core was taken at the merchantable stem mid-length; and approximately 2-inch-thick disks were cut from the butt of the lower log and from the top of the upper log. Sections were cut from these disks and cores for determining the fibril angles.

Fibril angle was measured as follows:

1. From each disk or core, a true radial surface was exposed from the pith to the cambial zone.
2. Sections were marked on this radial surface at 5-year intervals from the pith to the cambial zone. For the larger butt sections, the intervals were marked every 10 years from the thirtieth ring to the cambial zone.
3. At each marked ring, thin sections were cut by hand using a razor blade. These sections were placed in water on a microscope slide, covered, and observed on the screen of a Reichert Veripan[2] microscope at a magnification of ×130.
4. The fibril angle was considered to be defined by the angle formed between the longitudinal axis of the tracheids and the aperature of the half-bordered pit pair in the crossfields of the ray parenchyma and the longitudinal tracheids (Shottafer et al. 1972). Angles were measured to the nearest degree using a protractor directly on the microscope screen. Measurements were made on earlywood tracheid crossfields.

For each thin section examined, three fibril angles were measured. These three measurements were then averaged to obtain the fibril angle for that location in the sample.

Results and Discussion

The relationship between the fibril angle and rings from the pith is generally accepted to be exponential. The data in this study, however, showed a high degree of variability (fig.1) which, from a purely statistical point of view, indicated a linear relationship. This variability may have been the result of the less well-defined characteristics viewed in the hand sections, taking measurements on earlywood tracheids, and/or the method of angular measurement used in this study. Consequently, both a linear and exponential model were evaluated. In either case, only (1) rings from the pith, (2) height location in the tree, and (3) the d.b.h. × rings-from-pith interaction were found to be statistically significant at the 0.05 level. The

[2] *The use of trade and company names is for the benefit of the readers; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.*

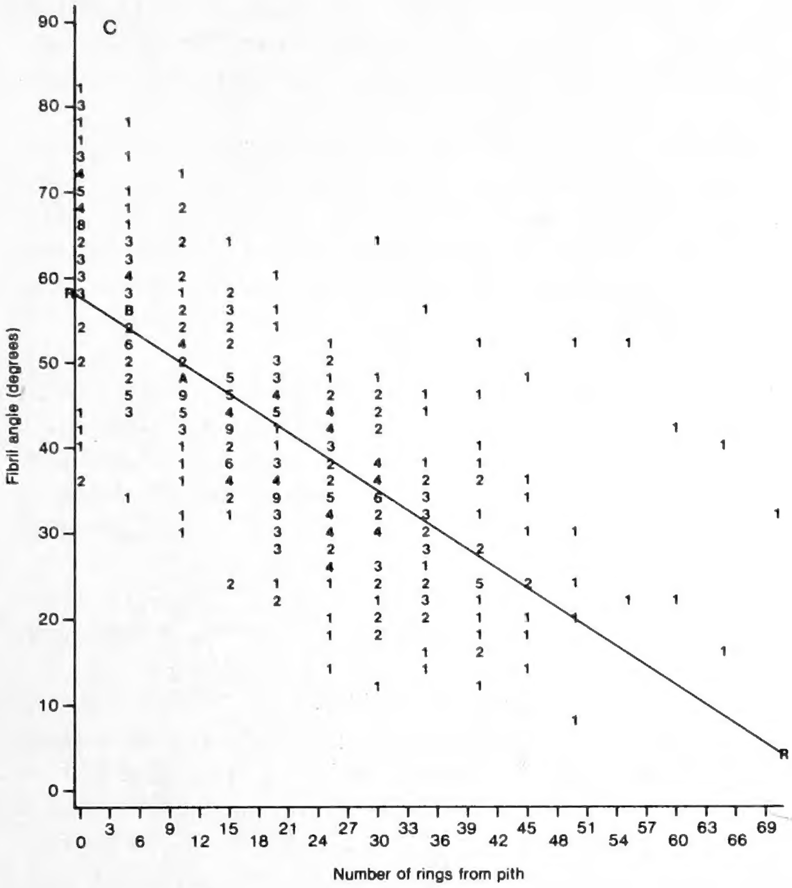


Figure 1.—Data plots of fibril angle versus rings from pith for the three heights; (a, butt; b, mid-stem; c, top) with linear regression curves.

contribution of interaction (3) to the correlation (R^2) value, however, was not considered sufficient to warrant its inclusion in the final models shown below.

$$FA = 51.6 - 0.462G + 15.3X - 1.19Y \qquad [1]$$

$$FA = e\,(XPH)\,(3.978 - 0.0114G + 0.281X - 0.0358Y) \qquad [2]$$

where FA = fibril angle (degrees);
G = rings from pith; and
X and Y = dummy variables representing location in tree coded as:

	X	Y
Butt	1	0
Mid-stem	0	1
Top	0	0

Because the heights of the mid-stem and top varied with the heights of the trees sampled, the data were evaluated also according to actual height in the tree. Plots of the linear curves obtained showed a distinct separation of the butt data and two other groupings, one consisting of the 17-, 33-, and 49-foot heights and the other, the 9-, 13-, 21-, 25-, 41-, and 57-foot heights. Although not totally consistent, these latter two groupings tended to follow the mid-stem and top categories, respectively. Thus, we retained the original categories.

For equation [2] the data were fit to the model using Marquardt's nonlinear least squares algorithm (Marquardt 1963). R^2 for both models was 0.590, with a standard error of estimate of 9.4 degrees.

While the exponential model did not improve the fit of the data, it still has features indicating it is more suitable for describing the relationship. Figure 2 shows the regression curves obtained from equation [2]. Two features should be noted. First, the slopes of the curves are more shallow through the juvenile zone than past studies would lead us to expect. Second, the slopes of the curves in the mature region (e.g., greater than 50 years of age) are not as flat as might be expected. Whether these conditions are the result of the regression process or truly representative of the young-growth ponderosa pine is not clear. The continuing decrease in fibril angle at the greater ages is similar, however, to that shown by Voorhies and Groman (1982). A linear relationship, on the other hand, would imply a continued constant decrease in fibril angle as the tree ages.

Although height location in tree was a statistically significant factor for all three locations evaluated, it appears that much of that significance is the result of the appreciably larger fibril angles in the butt material. The steeper negative slope seen in the curve for the butt material as compared with the other two locations is important. This could have an effect on the amount of warp that develops in lumber.

Although our earlier study (Markstrom et at. 1984) indicated it was not possible to correlate the fibril angle with warp development, the possible relationship is of enough importance to merit some discussion. Crook and bow are warp primarily caused by differences in longitudinal shrinkage on opposite sides of a piece of lumber. A very steep negative slope in the fibril angle curve indicates a relatively large difference in fibril angle would occur on opposite sides of a piece of wood cut from that location. This would likely result in differential longitudinal shrinkage. Thus, in the cases where more crook has been reported in lumber cut from butt logs (Blake and Voorhies 1980, Maeglin and Boone 1983), or where the amount of warp is related to smaller log diameters (Markstrom et al. 1984), a contributing factor may be the fibril

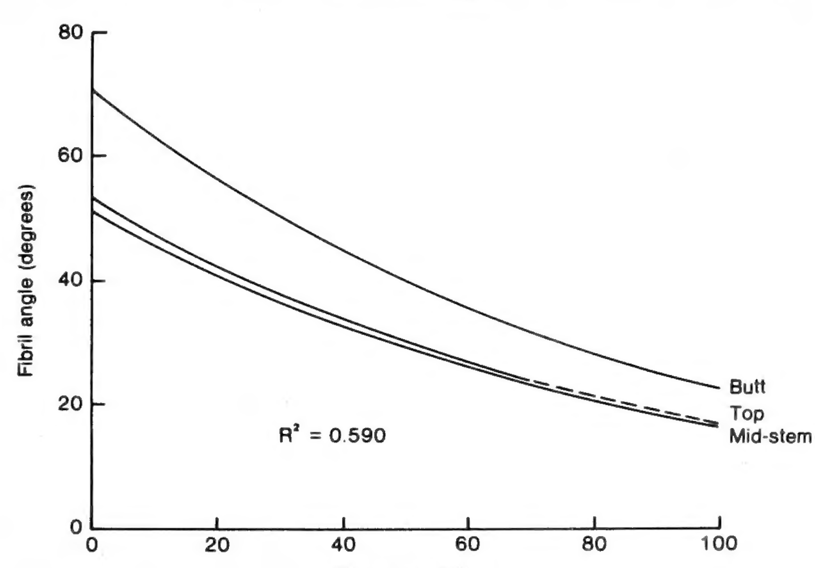


Figure 2.—Regression curves for fibril angle versus rings from pith for three X locations in ponderosa pine.

angle differential present in the juvenile wood. It must be emphasized, however, that the impact of fibril angle is most likely quite small. Other gross features (i.e., grain orientation, knots, compression wood) are expected to have more influence on the behavior of full-sized wood members.

Conclusions

1. The fibril angle in young-growth southwestern ponderosa pine is related to rings from the pith (i.e., age and diameter) and height location in the tree.

2. Differences in fibril angle related to height location in the tree are heavily influenced by the greater fibril angles in the butt material.

3. Site index and diameter breast height are not significantly related to fibril angle.

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