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Forest Products Laboratory

JMFA—An Interactive Java Program for Determining Microfibril Angle From X-ray Diffraction Data

Background

Much of our future timber supply is expected to come from improved softwood and hardwood trees grown on managed plantations or from small-diameter timber removed during forest management operations. This short-age-rotation resource will contain greater proportions of juvenile wood than does the present resource.

Research has demonstrated that juvenile wood has substantially lower mechanical property values than mature wood, which generally accounts for the inferior properties of short-rotation plantation wood compared with those of long-rotation timber. One can respond to these reductions in properties by attempting to improve silvicultural practices. Improved silvicultural practices require improved tools for monitoring stand quality. Measuring microfibril angle (MFA) holds promise as one such tool.

Wood cells are made up of multiple layers: a primary layer (P) and three secondary layers (S1, S2, and S3) (Fig. 1). The secondary layers consist of helically arranged cellulose microfibrils oriented toward the long axis of the tracheid. The thickest of the secondary layers is the S2 layer, and its properties strongly influence the properties of the wood fiber. Microfibril angle is measured as the angular deviation from the vertical of the microfibrils in the S2 layer.

Orientations of microfibrils in the S2 layer of juvenile wood tracheids vary widely both within and among trees of a species. In loblolly pine (*Pinus taeda*), for example, the MFA in mature wood is small, averaging 5° to 10°. In juvenile loblolly pine, the MFA is large, averaging 25° to 35°. The MFA is often as high as 50° in the annual rings next to the pith and decreases outward in the juvenile core. The decrease in MFA often continues well beyond the juvenile core. Evidence strongly suggests that the MFA of the S2 layer of the woody cell wall is a critical factor in the mechanical behavior of wood. The S2 MFA has a significant influence on tensile strength, stiffness, and shrinkage of wood. We conclude that MFA can be used as a selection tool in plantation management.

Given that our future timber supply is expected to come from shorter rotation forests, definitive information is needed on the influence of MFA on lumber properties so that selection and utilization methods can be adjusted accordingly.

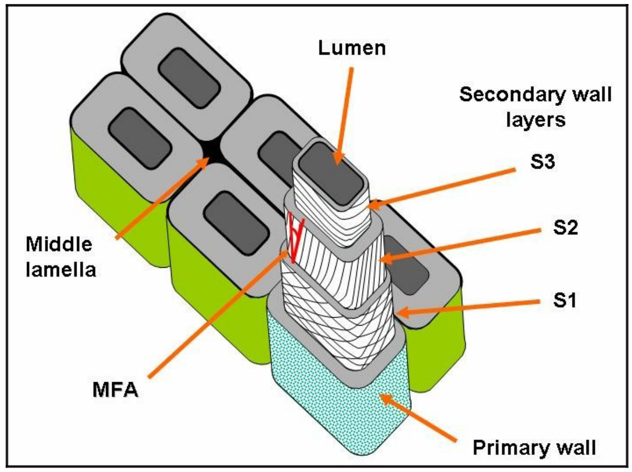

Figure 1. Wood cell structure.

We are developing a new curve fitting tool that permits us to reduce the time required to evaluate MFA x-ray diffraction patterns. Because this tool reflects the underlying physics more accurately than existing tools, we expect it to yield more accurate estimates of MFA.

Method of Measuring MFA

Traditional methods for determining the MFA of the S2 layer have been based on the orientation of the cross-field pit apertures, the maximum extinction position using polarizing light, the use of fluorescence light microscopy to enhance checks, and the orientation of iodine crystals that form in induced checks. Much of the current literature has been developed using these techniques, but these methods are slow and tedious.

X-ray diffraction techniques have also been used to determine MFA. Recently, researchers have done work to refine x-ray diffraction as a much more rapid technique for measuring MFA.

This technique uses the diffraction pattern created by the interaction of x-rays with wood tissue to determine MFA. A group of fibers is irradiated perpendicular to the fiber length by a narrow, monochromatic x-ray beam. A diffraction pattern is produced by the crystalline cellulose structure and recorded on film or by an electronic detector. This pattern consists of a series of arcs that are spaced apart by a number of well-defined concentric circles. The diameters of the concentric circles are indications of the spacing of the crystalline planes within the cellulose crystalline fibrils.

Researchers derived an equation that relates the locations of the spots of high x-ray intensity on the back plane of the x-ray apparatus to the Bragg angle associated with the x-rays, the rotation of the wood cell, and the MFA.

What We Are Doing

We are developing a new graphically interactive Java program that yields rapid analyses of microfibril x-ray diffraction patterns. In addition to leading to speedy analyses, this program makes use of an improved model of the underlying physics that should yield more accurate MFA estimates.

The objective of our current work is to test and improve this program in several ways:

- Work on complications that occur when the front face of the cell is tilted down or up.
- Conduct a check of the program that involves its estimates of cell rotation. (We can control rotation with our experimental apparatus in the sense that we can rotate the clip on which the specimen is mounted through a full 360°. If our model is performing well, the estimates of rotation should be well correlated with the known rotations, and the microfibril angle estimate should not change.)
- Work on improving the manner in which the nonlinear least squares model takes into account differences in the variabilities and amplitudes of the Gaussians associated with front/back or left/right cell faces.
- Modify the model to handle wood cells with circular cross sections.

Even as we seek to improve the program and the mathematical model upon which it is based, we are making use of the program in analyzing the results from a large database of recently acquired x-ray profiles.

A beta version of the JMFA program can be run on sample data at http://www1.fpl.fs.fed.us/mfa0.html. (The program requires that users have a Java Runtime Environment (JRE) installed on their machines.)

Learn More About It

Larson, P. R., Kretschmann, D. E., Clark III, A., Isenbrands J. G. 2001. Juvenile wood formation and properties in southern pine. Gen. Tech. Rep. FPL-GTR-129, Madison, WI, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 42 p.

Verrill, S. P.; Kretschmann, D. E.; Herian, V. L. 2001. JMFA—A graphically interactive Java program that fits microfibril angle X-ray diffraction data. Res. Note FPL-RN-0283. Madison, WI: U. S. Department of Agriculture, Forest Service, Forest products Laboratory. 44p.