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Detecting Juvenile Wood in Southern Pine Logs with Brush Electrodes

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Abstract

Log scanning to determine internal characteristics to maximize lumber value has been a long-term goal of the sawmilling industry. Juvenile wood is wood formed in southern pine trees during the first 10 years of growth. Juvenile wood is characterized by wood with high moisture content and that undergoes a high degree of longitudinal shrinkage during kiln drying. This shrinkage results in large amounts of warp that produce lumber degrade and very high value loss. Detection of juvenile wood prior to sawing logs will allow application of sawing patterns and drying procedures that result in reduced influence on the final lumber value. Our research tested EIT scanning with brush electrodes to determine the potential for detecting juvenile wood in green southern pine logs. EIT and computed tomography (CT) images were compared to determine that juvenile wood could be detected with acceptable.

Introduction

In the early growth of many tree species, a wood type termed *juvenile wood* is formed during the first 10 years of life (Tasissa and Burkhart 1998). Juvenile wood has several properties that negatively influence its utilization with a mojor one being high degree of longitudinal shrinkage, that is up to 10 time higher than that of normal wood. This high degree in shrinkage causes increased lumber warpage and significant lumber value loss. Juvenile wood has thinner cell walls larger lumens than normal wood. When southern pine wood is green this results in 147% moisture content compared to about 100% in normal wood (Lamb and Wengert 1987).

Knot presence, frequency and location also decrease log quality and value. Researchers have investigated the benefit of scanning logs for defects prior to sawing followed by computer analysis to position defects in lumber to optimize lumber value (Peter 1967; Tsolakides 1969; 1980; Steele et al. 1994). Their estimates of potential lumber value improvement ranged from 9 to 21 percent.

Although various technologies for internal log scanning have been tested, CT imaging is the most frequently investigated solution for obtaining internal images Holoyen et al. 1999). NMR scanners have also been tested for this purpose and acceptable images were produced (Chang et al. 1989). However, both CT and NMR technologies remain too slow and expensive for industrial log scanning applications. White (1996) employed an Electrical Capacitance Tomography (ECT) device to detect internal rot in wooden poles but no attempt to detect juvenile wood or knots was attempted. Salvolainen et al. (1996) successfully developed an EIT system capable of imaging internal log images showing knots. However, the sensors employed metallic screws which render this method impossible to utilize for the scanning of moving logs.

Steele and Cooper (2004) have been granted U. S. Patent No. 6,784,672 for the Through-Log Density Detector (TLDD), an EIT device for detecting differential densities in logs such as for wood types (juvenile and compression wood) and knot or rot presence. Electrodes are non-penetrating with one embodiment utilizing brush electrodes to allow movement of sawlogs past electrodes.

Detection of juvenile wood prior to sawing logs will allow application of sawing patterns and drying procedures that result in reduced influence on the final lumber value. Previous studies employing the TLDD with static circular electrodes were successful in detecting juvenile wood (Cooper et al. 2007). However, provision for log during scanning required the testing of the efficacy of brush electrodes performed in this study.

Objective

The objective of this study was to determine the capability of brush electrodes to produce EIT information sufficient to produce an image of the juvenile wood core of green southern pine logs.

Experimental Procedures

A log section of 91.4 cm (36-in.) long was cut from a freshly felled loblolly pine tree. Following initial harvesting, the log sections were cold stored at 34°C. Twenty-four hours prior to scanning the log sections were allowed to warm to ambient temperature and debarked to allow full electrode contact with debarked surface and scanned along the log section length at 1.3-mm intervals with a GE Lightspeed CT scanner. Images of log cross sections were created from CT imaging software.

The TLDD system employs cutters to machine one cm wide grooves down log section length to guide the brush electrode travel during scanning (Figure 1). Depth is variable and depends on the eccentricity of the log and presence of bump, dimples or swellings on log surface where the cutter path is machined. Mean depth is approximately one cm. TLDD scanning was performed utilizing eight equidistant stainless steel brush electrodes as shown in Figure 1. Each electrode contained 88.9-mm-long (3.5-in.) brushes attached to a circular frame. Electrodes were orientated at 45-degree angles with respect to the direction of log travel.

Log sections were scanned at 25.4 mm (1-in.) intervals over the log section length beginning and ending approximately 10.2 cm (4 in.) from log section ends to reduce the end-effect influence. With the TLDD setup employed in this study, a radio frequency signal was generated, coupled to a current source and a current was applied between one adjacent electrode pair with the resultant voltage sensed at the remaining 7 adjacent electrode pairs as shown in Figure 2. This process was performed for each of the 7 remaining adjacent electrode pairs resulting in 64 observations per cross sectional log scan. Digital EIT images of the log cross sections were created from TLDD log scan data with EIDORS imaging software (Vauhkonen et al. 2000).

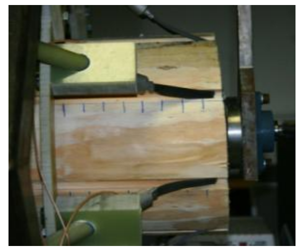


Figure 1: Photo of brush electrodes in the TLDD scanning system.

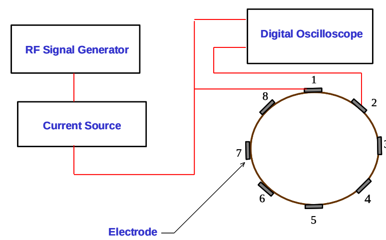
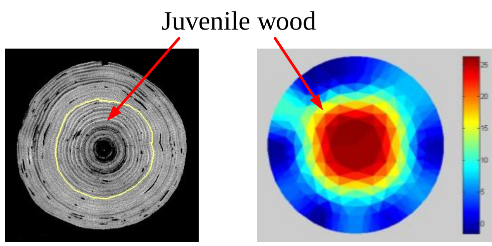


Figure 2: Block diagram of the TLDD scanning system.

The current TLDD switching system cannot capture the 64 observations required to allow data to be gathered for a moving log. The current study was performed to determine if the brush electrodes would provide sufficient signal accuracy to allow development of an EIT image. The log was scanned at 25.4 mm intervals along log-section length by moving the log and stopping it to allow the 64 observations to be captured at each cross sectional scan position.

In the CT images, juvenile wood was defined as the total area of wood contained within the first 10 annual growth rings. Juvenile wood was defined in the TLDD images as the circular area near log center with color indicator values ranging from 17 to 26 where a color value of 26 indicating a stronger influence on the electrical field due to the higher moisture content of juvenile wood. Following delineation of juvenile wood in the CT and TLDD images, Matlab® software computed the area defined in each.

TLDD cross-sectional images were compared to CT images, at the same location along log length, to determine accuracy of TLDD juvenile wood estimation. For this purpose, the juvenile wood area was manually outlined in the TLDD and CT images as shown in Figure 3. Microsoft® Paint software traced juvenile wood peripheries based on specified definitions of these wood types. The color value of 26 was closest to log center indicating that, as expected, the highest moisture juvenile wood was developed at the tree pith. As the juvenile wood transitioned toward a lower moisture content mature wood, the influence on the electrical field varies resulting in a color value decrease from 26 to approximately 17 and finally, to a value of 8 for mature wood.



(a) (b)

Figure 3: Cross-sectional CT (a) and TLDD (b) images showing the method for outlining juvenile wood.

Accuracy of TLDD imaging was expressed as the difference in juvenile wood area between the TLDD and CT images. Researchers felt that this difference measure was adequate because juvenile wood was always centered correctly in the TLDD images at log center. Therefore, the difference in juvenile area definition between TLDD and CT images occurred only at the periphery of juvenile wood core, allowing area to be a proxy for positional error computation.

Experimental design

A completely randomized experimental design was employed to compare CT and TLDD log scanning methods. The CT and TLDD scanning methods were entered as independent treatment variables while juvenile wood area was the dependent variable in analysis-of-variance (ANOVA) Equation 1. All comparison-of-means tests were performed at the 0.05 significance level.

$$\text{Juvenile wood area} = \mu + \text{METHOD} + \varepsilon \qquad (1)$$

where: μ = overall mean juvenile wood area (cm^2); METHOD = CT or TLDD log scanning method and ε = error term

Results

The Equation 1 METHOD treatment variable was found to be significant. Figure 4 shows the comparison-of-means test results for mean juvenile wood area by scanning method. The TLDD log scanning method yielded a mean juvenile wood area response that was a significant 54.8 cm^2 (37-percent) smaller than for the CT images. This result indicates a consistent underestimation of TLDD juvenile wood area caused by the definition that we adopted for the TLDD juvenile wood core area. Redefinition of the value code defining the outer limit of juvenile wood areas would be a simple means to correct this underestimation error.

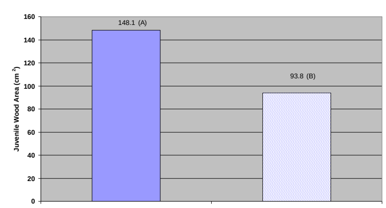
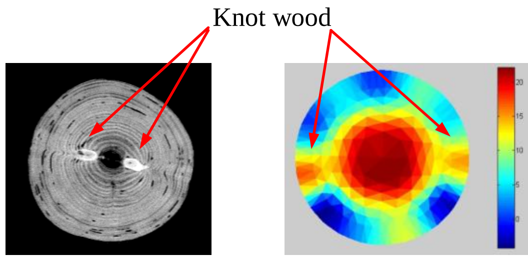


Figure 4: Juvenile wood area versus scanning method.

A brief visual comparison on CT and TLDD images (Figure 5) indicated that knots were differentiable in the images. Future research will examine the precision of knot detection.

TLDD scanning with brush electrodes shows potential for juvenile wood size estimation and knot detection in southern pine logs. However, additional research is needed to refine and develop this technology prior to commercialization.



(a) (b)

Figure 5: Cross-sectional CT (a) and TLDD (b) images showing knot wood.

Summary

Cross-sectional images produced by CT and TLDD technologies were produced by scanning of a green southern pine sawlog section at 25.4 mm (1-in.) intervals along log length. The TLDD employed EIT methodology with a circular frame holding 8 equidistant brush electrodes. Images from the TLDD system underestimated juvenile wood area and diameter by 37 percent and 23 percent, respectively when compared to images from CT tomograms. Knot wood yielded color values that differed from juvenile wood. Relatively simple modification of the color value indicating juvenile wood margin was judged by researchers a feasible means to correct the consistent TLDD underestimation of juvenile wood size.

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