DETECTING SINKER-STOCK LUMBER WITH ULTRASOUND MEASUREMENTS

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ABSTRACT

Bacterial infestation of the sapwood tissue resulting from wet storage of logs prior to processing destroys ray parenchyma. Damaged rays act as mass transfer pathways. Lumber with bacterial damaged rays, referred to as sinker-stock, results in excessive uptake of preservatives during treatment that requires further processing, such as drying. A window and door manufacturer requested an investigation to develop a reliable method for inline detection of sinker-stock lumber. An ultrasonic technique was used in this study based on a hypothesis that damaged rays would reduce intensity of sound waves transmitted through the wood in the radial direction. Intensity of sound waves through the thickness of sample sections was measured across the width including at least one through the radial direction. These measurements were done with a pair of 500 kHz transducers and with a pair of 120 kHz air-coupled transducers to obtain intensity imaging of the entire section. Based on these measurements, samples were classified into sinker, intermediate, and non-sinker groups. Microscopic examinations of samples verified that samples with low intensity measurements had nearly complete damage of the rays, samples with intermediate intensity measurements contained sporadic ray damage, and samples with little ray damage corresponded to samples with high intensity measurements. It is concluded that it is feasible to use multiple pairs of air-coupled transducers for inline detection of sinker-stock lumber.

Keywords: Ponderosa pine, sinker-stock lumber, ultrasound transmission, ray tissue.

INTRODUCTION

Researchers at the Forest Products Laboratory of the University of California (Ellwood and Ecklund 1959a,b) first discovered the problem of excessive wood preservative uptake associated with ponderosa pine sinker-stock. These studies indicated that storing ponderosa pine (*P. ponderosa*) and sugar pine (*P. lambertiana*) logs in ponds as short as one month drastically increased porosity of the sapwood. The destruction of wood ray tissue by bacteria under anaerobic conditions was identified as the cause of increased sapwood porosity. Pond-stored logs with bacterial infestation usually sink to the pond bottom, and lumber manufactured from these sunken logs is referred to as sinker-stock.

Bacteria utilize reserve materials such as simple sugars, starch, and oils in sapwood rays. In the process of bacterial growth, the walls of

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the ray cell also are destroyed, turning the damaged ray tissue into open channels for mass transfer of vapors and liquids. Bacterial growth in pond-stored logs and subsequent wood destruction are confined only to ray parenchyma in the sapwood because of available food in these cells. The sinker-stock problem is more serious with ponderosa pine than with sugar pine because ponderosa pine sapwood is wide and usually contains more than 100 growth rings while sugar pine has a narrow sapwood (Panshin et al. 1964).

A window and door manufacturer is currently using an inline sinker-stock detection method but has requested an investigation to develop a more reliable method. The current inline detection method is based on the principle that sinker-stock lumber quickly absorbs mineral spirit that has a low surface tension. Because of ray orientation, sound waves transmit faster with stronger transmitted signals in the radial than the tangential direction. Bacterial damage of rays causes an increased porosity and disruption of continuity in the radial direction, and thus can reduce the speed and intensity of sound transmission. An ultrasonic technique was used in this study based on a hypothesis that damaged rays would change the manner sound waves transmit through the wood in the radial direction.

MATERIALS AND METHODS

Twelve 6/4 ponderosa pine sample boards, six sinker and six non-sinker as classified by the company, were obtained without additional information such as duration and method of log storage and drying schedules. Each board was cut at about 2-ft. intervals (but avoiding apparent defects, mainly knots) into three to four 12-in. sections dependent upon board length. Moisture content determination after utrasound measurements indicated that these sample sections contained 5.5% to 7.5% moisture.

Contact measurement

Contact measurements for the peak amplitude of the transmitted signal in volts were done with a pulser/receiver (Panametrics 5052PR) in conjunction with an oscilloscope (Tektronix 2252) using a pair of 500-kHz transducers. Three to five measurement locations approximately 2.0 in. apart across the grain were established, depending on sample width, ensuring one true radial measurement. Vacuum grease was used as the coupler to ensure good contact during transmission measurement. All measurement parameters, such as gain, energy level, damping, etc., were held constant.

Scanning measurements

The ultrasonic images were obtained in ambient laboratory environment using air-coupled ultrasound in the transmission mode. The transmitting transducer was placed approximately 1 in. from one surface of the sample section and the receiving transducer was placed approximately 1 in. from the opposite surface. The two transducers were mounted on a yoke fixture, aligned to face each other colinearly, and moved by a motorized scanner to produce the ultrasonic "C-scan." A scanning increment of 0.1 in. was used in both vertical (across the grain) and horizontal (along the grain) directions at a scanning speed of 20 ft/min. The transducers had a center frequency of 120 kHz, and the peak amplitude of the transmitted signal was used in making the image. The resulting "C-scan" therefore showed the transmitted signal amplitude as a function of position on the board. The air-coupled transducers and the pulser-receiver were purchased from QMI, Inc. in Huntington Beach, California.

Microscopy

Sample sections with three distinctive levels of peak amplitude of the transmitted signal in the radial direction, those with consistently low readings, with inconsistent readings, and with consistently high readings, were selected for microscopic examination to determine the degree of bacterial degradation of the ray tissue. Small specimens approximately 0.25 sq. in. in cross-section (tangential × longitudinal) and 1.5 in.

long in the true radial direction were cut from sample sections, boiled for 30 min, embedded in polyethylene glycol (PEG) 1540, and the smooth tangential surfaces were prepared with razor blades as described by Exley et al. (1974). Thin slices of section about 500 μm thick containing the smooth tangential surface were removed from the ends (board surfaces), half way to the core and from the core of the 1.5-in. long samples, followed by removing the embedding PEG with distilled water and dehydration of the thin slices using a solvent exchange drying method described by Thomas and Nicholas (1966). Specimens were examined with a JOEL 850 environmental scanning electron microscope (SEM) for integrity of ray cell walls in rays.

RESULTS AND DISCUSSION

Results of contact measurements for transmitted sound signal of all samples are presented in Table 1. It is clear in Table 1 that the highest peak amplitude in each sample always was in or near the radial direction and that there was a wide disparity in radial peak amplitude among samples, ranging from lower than 0.1 volts to over 1.0 volts. Based on radial peak amplitude measurements, samples were roughly divided into three groups: sinker, intermediate, and non-

TABLE 1. *Contact measurements of presumed non-sinker and sinker-stock ponderosa pine sample boards for peak amplitude of transmitted signals.*

Presumed sinkers peak amplitude (volts)				
Board 1[1]	SX A	SX B	SX C	SX D
Radial[2]	0.012	0.056	0.125	
M2	0.009	0.012	0.040	
M3	0.012	0.010	0.010	
Board 2				
Radial	0.045	0.042	0.015	
M2	0.088	0.037	0.027	
M3	0.080	0.046	0.040	
Board 3				
M1	0.074	0.282	0.170	
Radial	1.240	1.242	1.230	
M3	0.140	0.056	0.098	
Board 4				
M1	0.404	1.200	0.478	0.550
Radial	0.945	0.885	0.810	1.100
M3	0.815	0.390	0.630	0.735
M4	1.090	0.252	0.326	
Board 5				
M1	0.139	0.110	0.051	0.047
Radial	0.660	0.394	0.384	0.223
M3	0.065	0.044	0.039	0.079
Board 6				
M1	0.079	0.044	0.124	0.192
M2	0.108	0.178	1.015	0.665
Radial	0.570	0.665	0.935	0.554
M4	0.130	0.111	0.103	0.280
M5	0.126	0.360	0.171	

Presumed non-sinkers peak amplitude (volts)				
Board 1	SX A	SX B	SX C	SX D
M1	1.275	1.075	1.176	
Radial	1.160	1.246	1.200	
M3	0.436	1.075	1.176	
Board 2				
M1	0.372	0.178	0.350	
Radial	0.572	0.620	0.642	
M3	0.114	0.808	0.306	
Board 3				
M1		0.196	0.150	
M2	0.632	0.976	0.452	
Radial	1.245	1.250	1.236	
M4	0.222	0.088	0.106	
Board 4				
M1	0.075	0.086	0.470	0.128
M2	0.035	0.025	0.064	0.025
Radial	0.620	0.790	0.620	0.520
M4	0.081	0.122	0.054	0.152
M5	0.140	0.068	0.112	0.184
Board 5				
Radial	0.933	1.060	1.045	1.065
M2	0.063	0.035	0.121	0.143
M3	0.123	0.114	0.153	0.108
Board 6				
M1	0.170	0.630	0.514	0.492
Radial	1.003	1.050	0.865	1.195
M3	0.228	0.250	0.890	0.246
M4	0.092	0.066	0.108	0.147

[1] Each sample board was cut into 1-ft-long sections (SX) at about 2-ft intervals.
[2] Three to five measurements (M1 to M5) approximately 1.5 inch apart were made across the grain containing one transmission measurement in the true radial direction (bold).

sinker, having low, intermediate, and high intensity readings, respectively. The window and door company that provided the sample boards currently uses a solvent absorption method to detect sinker-stock lumber, in which lumber pieces that quickly absorb a low-surface-tension organic solvent are identified as sinkers. According to ultrasound measurements, of the six presumed sinker boards two each were reclassified as sinker, intermediate, and non-sinker. Of the six presumed non-sinker boards, two were reclassified as intermediates and four as non-sinkers. Variations in radial as well as across grain peak intensity in each board also were observed. For example, radial measurements for Sections A, B, C, and D of Board 4 were 0.945, 0.885, 0.810, and 1.100 volts, respectively, while some non-radial measurements showed higher signal intensities than the radial measurements. Such variation in transmitted signals along the rays and across the grain indicates a non-uniform pattern of bacterial degradation of rays.

Ultrasonic scanned images based on intensity of the transmitted signals show a very high correlation with contact intensity measurements. A distinctive high intensity band corresponding to the radial direction was observed in sample sections with high contact radial measurements (Fig. 1). In scanned images of sample sections that were classified as sinkers by very low radial contact measurements lacked such a continuous high intensity band along the radial direction and often showed scattered small high intensity regions (Fig 2). For those images of samples sections classified by the contact measurement as intermediates, a partial high intensity band corresponding to the radial band was observed (Fig 3).

Microscopic examinations showed that samples with high intensity of transmitted signals in the radial direction corresponded to little ray degradation (Fig. 1), while low intensity readings were always associated with a high degree of ray decomposition (Fig. 2). Samples with intermediate intensity readings often corresponded to sporadic ray damage (Fig 3). The SEM photomicrograph in Fig. 1 shows that thin-walled ray cells in all rays were intact except those in one ray at far upper left that sustained some damage. Figure 2, however, shows that thin-walled ray cells in all rays were decomposed, leaving the rays almost empty except thick-walled ray tracheids. Microscopic examination of samples with intermediate intensity of transmitted sound signal shows that ray cells in some rays were severely decomposed, while those in the neighboring rays remained relatively undamaged (Fig. 3).

With confirmation of microscopic analysis, it is clear that both the ultrasonic contact measurement and the "C-scan" methods are more reliable than the solvent absorption method to identify sinker-stock lumber. In addition, these ultrasonic methods also are able to measure the extent of bacterial ray damage in lumber. The contact measurement method, however, cannot be used as a tool for inline detection to accommodate the production speed. It may be technically and economically feasible that an inline detection system can be designed and used for accurate segregation of sinker-stock lumber based on the scanning method with air-coupled transducers.

CONCLUSIONS

It is demonstrated that ultrasound intensity measurements are able to detect sinker-stock lumber. This is reinforced with microscopic observations that ray degradation increased wood porosity and thus reduced intensity of sound transmission in the radial direction. It is also concluded that the current method used by the company to detect sinker-stock lumber is not reliable. Non-uniform distribution of ray degradation, as demonstrated with microscopic observations of intermediate samples, implies that spot-checking also is inappropriate. Localized or superficial liquid absorption examinations may or may not be indicative of truthful classification of the board being examined. Multiple inline air-coupled transducers may be a potential sinker-stock detection method.

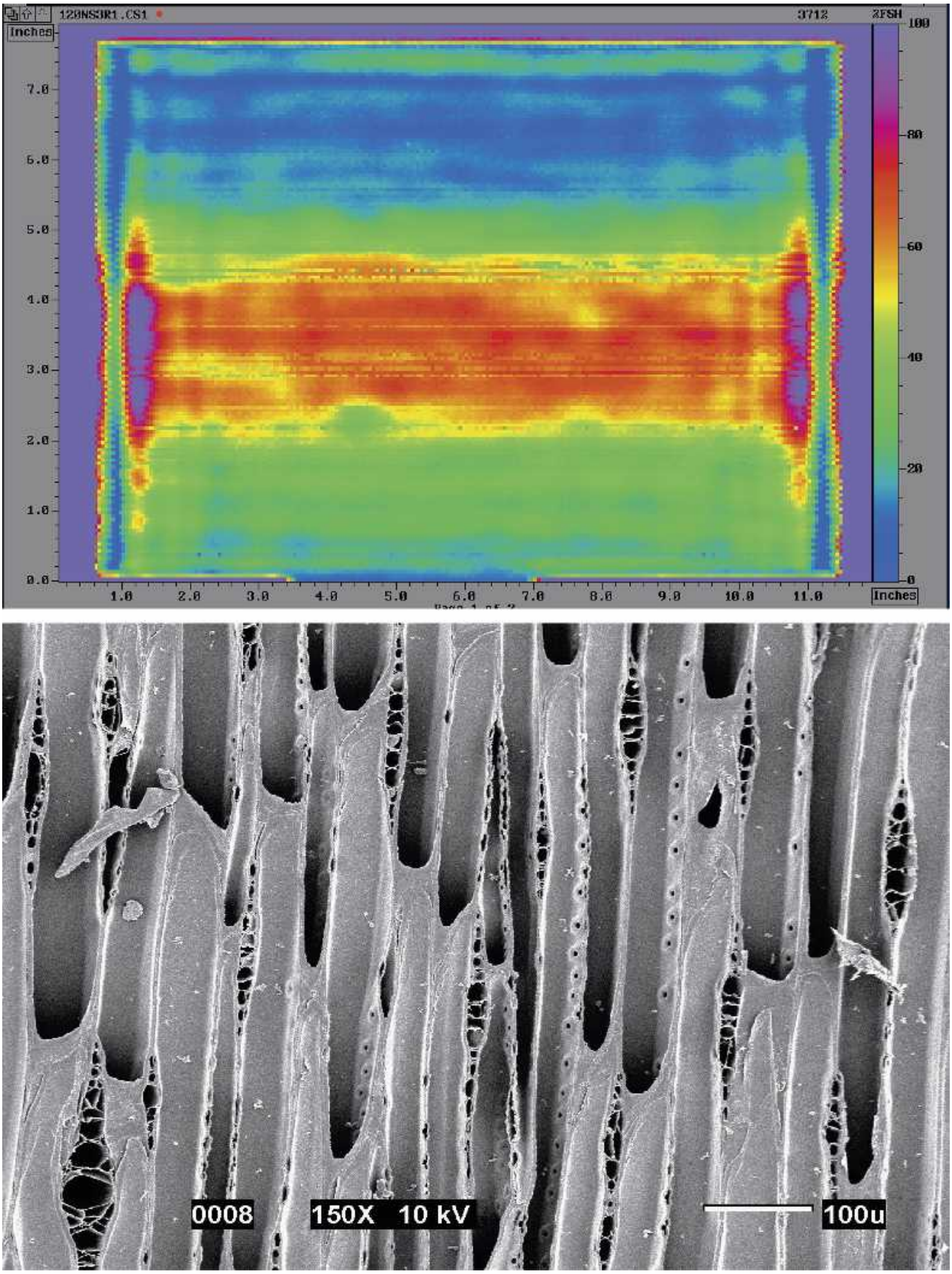

FIG. 1. Upper: ultrasonic scanning image of a non-sinker-stock ponderosa lumber section showing a relatively uniform and high intensity band of transmitted signals in radial direction (middle portion); Lower: SEM photomicrograph of a corresponding lumber section with undamaged rays as viewed from the tangential surface; note that both ray cells and ray tracheids are intact.

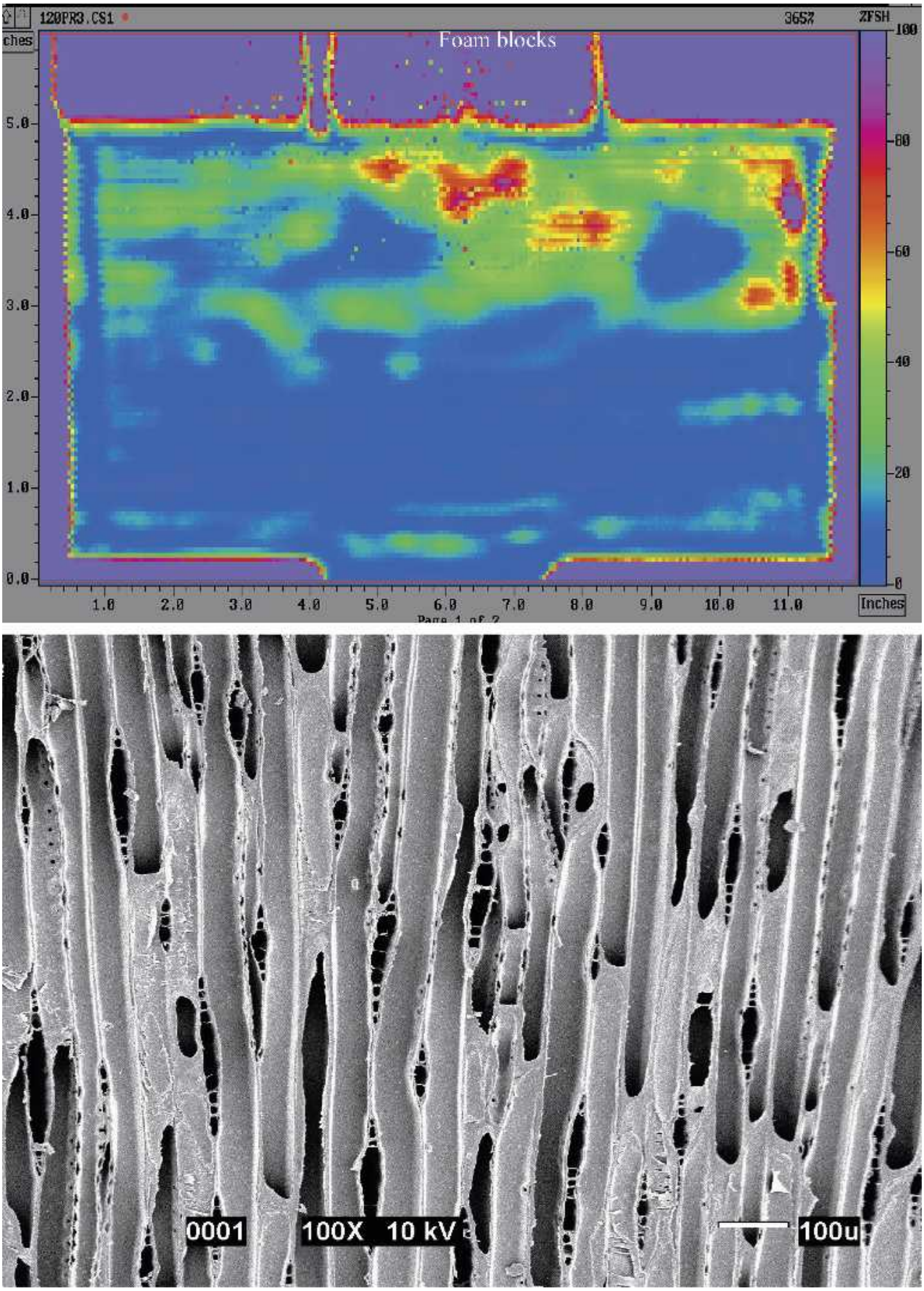

FIG. 2. Upper: ultrasonic scanning image of a sinker-stock lumber section showing low intensity of transmitted signals in radial direction (top portion); Lower: SEM photomicrograph of a corresponding lumber section, showing extensive damage of ray cells and intact ray tracheids as viewed from tangential surface.

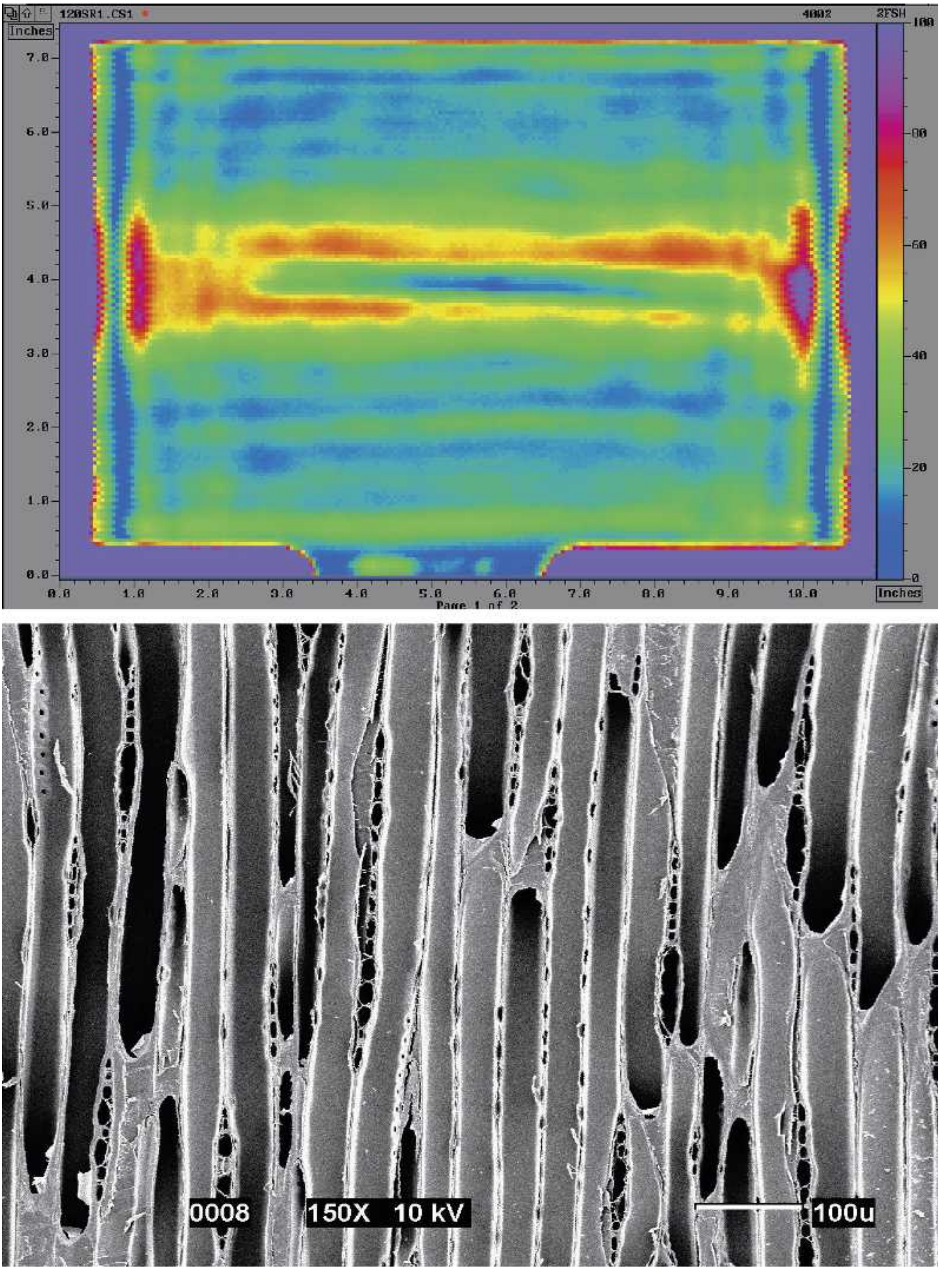

FIG. 3. Upper: ultrasonic scanning image, showing profile of intensity of transmitted signal in radial direction (middle portion); Lower: SEM photomicrograph of a corresponding lumber section, showing sporadic rays damages as viewed from tangential surface.

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