ULTRASONIC SCANNING FOR PALLET PART GRADING

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ABSTRACT

Sorting and grading of wooden pallet parts are key factors for pallet manufacturing quality and pallet durability. The feasibility of ultrasonic scanning for defect detection in pallet manufacturing is examined in this report. Scanning was conducted by two pressure-contact rolling transducers in a pitch-catch arrangement. Pallet part deckboards were fed through the transducers and data were collected, stored, and processed with software written in the LabView™ environment. Defects were characterized on the basis of time of flight, pulse energy, and pulse duration of the received ultrasonic signals. Values of the ultrasonic parameters changed rapidly in the region of defects. This relative change of parameter values with respect to values for clear wood can be used to locate, identify, and quantify various pallet part degrades. Results demonstrate that real-time, on-line inspection of wooden pallet parts is possible by ultrasonic scanning.

INTRODUCTION

In the United States, 30-40% of sawn hardwoods produced annually goes into the manufacture of wooden pallets (Bush and Araman 1998). This constitutes the single largest use of sawn hardwood logs. Each year, over 400 million new wooden pallets are manufactured, consuming 4.5 billion board feet of hardwood lumber (Bush et al. 1997). The use of softwood lumber for pallet construction is somewhat less; about 1.5 billion board feet. Together, pallet manufacturing's use of hardwoods and softwoods is a substantial sink for the wood resource.

Roughly 4 billion board feet of wood pallets and containers are discarded annually, due to pallet damage, one-way use, delivery to a location where they are not re-used, or improper design for a particular use (Aruna et al. 1997). Many wooden pallets consist of two types of components: stringers, the structural center members that support the load, and deckboards, the top and the bottom members that provide dimensional stability and product placement. These deckboards and stringers are produced from low-grade wood, either from lumber or from the center cant material of logs. Cant materials have a higher percentage of defects and have less market value for other solid wood products.

High-grade wooden pallets require high-quality pallet parts for their manufacture, which ultimately gives them a much longer life cycle and promotes multiple use. Manual grading and sorting of pallet parts is a slow and inaccurate process, which depends on the individual skill of the grader. Moreover, the presence, location, and extent of defects in pallet parts are often difficult to ascertain accurately, making the grading system complicated. These observations suggest that an automated inspection system for pallet parts can be very useful, and an economic study (Schmoldt et al. 1993) has demonstrated profit potential.

Individual pallets are constructed from a variety of wood species and from parts with differing strength properties, resulting in pallets with random and unknown strength and durability. Descriptions of allowable defects for minimum pallet component quality are shown in Table 1 (Anon 1994). These data are incorporated from the Standards for Wood Pallets, National Wooden Pallet and Container Association (NWPCA). It is obvious from this table that defect information is important for manufacturing quality and durable pallets. For the last few years, research has been conducted to develop an automated pallet part inspection system (Schmoldt et al. 1994, 1996, 1997). The feasibility of defect detection based on ultrasonic scanning has been reported by many other researchers (e.g., Ross et al. 1992, 1995, Fuller et al. 1995, Kabir et al. 1997). Visual grading rules for deckboards are presented in Table 2.

This study describes preliminary efforts to develop an automated ultrasonic imaging system to locate and identify pallet part degrades. This information can then be used to automatically grade and sort parts according to established visual grading rules. The following sections describe our current scanning systems and present results from some initial scans of defects on deckboards from two wood species.

Table 1. Minimum pallet component quality.

Defect	Description	Defect limitations	
		Multiple-Use (M)	Limited Use (L)
Sound knots	Maximum portion of the cross section affected	1/2	7/8
Frequency of knots	Number of maximum size knots per component	2 in 6 in.	1 in every half length of component
Unsound knots and holes	Maximum portion of the cross section affected	1/4	2/3
Wane	Maximum portion of the actual deckboard or stringer board width by thickness	1/4 x 2/3 (exposed) 1/3 x 2/3 (non-exposed)	3/8 x full thickness (exposed) 1/2 x full thickness (non-exposed)
Decay	Maximum portion of the cross section affected	1/4	1/4

Table 2. Grading criteria employed for deckboards according to defect type, size, location, and extent.

Defect	Description	2 & BTR	3	4
Sound knot	Maximum dimension across width of the board	1/4 of board width	1/3 of board width	1/2 of board width
Location of knots	Knots in the edges and end 3" of the board	1/2" diameter	1/4 of board width	1/3 board width
Unsound knot/holes	Knot holes, unsound or loose knots, and holes	1/8 of board width	1/6 of board width	1/4 of board width
Cross grain	Slope of general cross grain Max. dimension of local cross grain	1" in 10" 1/4 board width	1" in 8" 1/3 board width	1" in 6" 1/2 board width
Splits, checks and shake	Max. length singly or in combination Defects 3" or less are ignored	1/4 of board width	1/2 of board width	3/4 of board width
Wane	Max. portion of cross section affected at point of deepest penetration	1/16 of cross section	1/8 of cross section	3/16 of cross section
Decay	Cross section deepest penetration	None allowed	1/8 of cross section	1/4 of cross section
Pith	In face of board boxed	None None	Full length 1/3 length	Full length Full length
Mismanufature	Max. 10" length; and max. cross section	1/6 of cross section	1/8 of cross section	1/2 of cross section

MATERIALS AND METHODS

Scanning Equipment

The ultrasonic scanning arrangement was designed by the Forest Products Division of Perceptron and purchased by the USDA Forest Service, Southern Research Station (Figure 1). The system consists of in-feed and out-feed roll beds, two pinch-rollers for part movement, and two rolling transducers which are mounted in an ultrasonic scanning ring. The bottom transducer transmits ultrasonic pulses and the top one receives them. Perceptron provided the necessary electronics and software to control material movement, signal generation, and waveform capture and analysis. Data were collected and stored by LabView™ software modules. We can easily plot the data against board length for a single scan line. The desire spatial resolution can be achieved by controlling roller speed and the number of pulses per second.

Deckboard Samples

Initially, yellow-poplar *(Liriodendron tulipifera,* L.) and red oak *(Quercus rubra,* L.) deckboards, of varying lengths and in the rough, green state, were collected from a pallet manufacturer. They were placed immediately

into cold storage to maintain moisture content levels near the fresh-cut condition. Average thickness of the boards was 1/2 inch, and lengths varied between 30-60 inches. Defects examined in this study were sound and unsound knots, cross grain, bark pockets, insect holes, splits, shake, decay and wane. A scan line was marked on each board through a defect of interest and scanning was performed along this line from one of the board's faces to the other face.
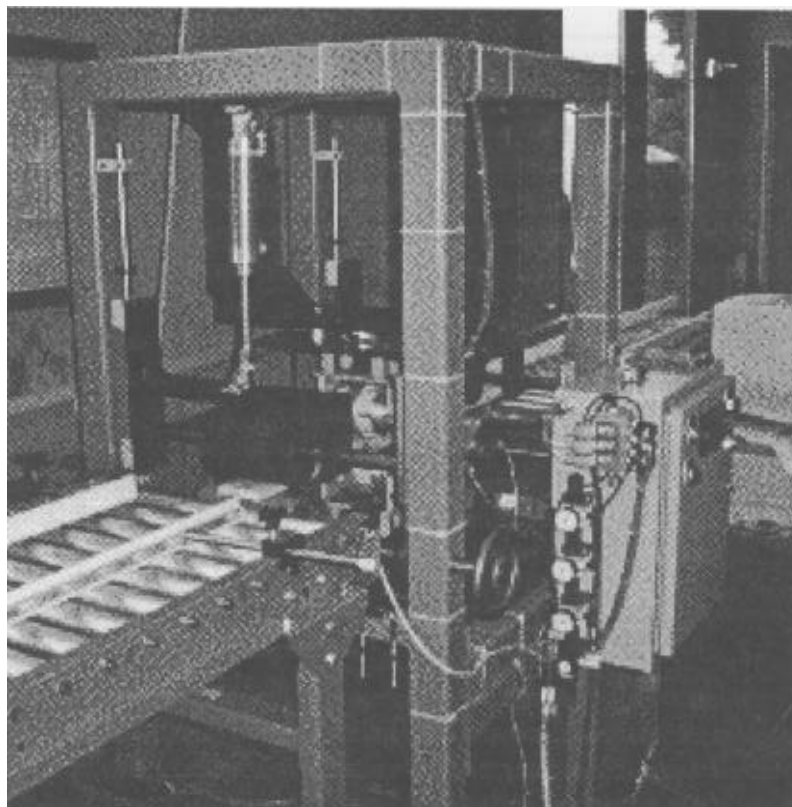

Figure 1. The scanning ring of the ultrasonic set up contains two rolling transducers and a set of pinch-rollers to move the board.

Scanning

Three boards were scanned for each defect type. The system is able to scan at board speeds as fast as 370 ft/minute. The data were collected for two scanning resolutions (or speed)—10 waveforms/inch (or 70 feet/minute roller speed) and 4 waveforms/inch (or 220 feet/minute roller speed). LabView software modules were written to plot collected data along the board length. Because this was an initial attempt to scan rough lumber with rolling transducers, we wished to know if scanning speed affected data collection reliability and repeatability.

RESULTS

A comparison of scanning resolution (rates) appears in Figure 4. Data collected at two different rates show almost identical values. Furthermore, repeated measurements along the same scan line result in very small coefficients of variation. More details on these tests can be found in Kabir et al. (2000).

Results appearing in Figures 2-3 demonstrate signal differences between various defects and clear wood regions. Only yellow poplar samples are shown here, but oak specimens behaved similarly. The presence and extent of the defect in a board can be identified by observing the change in ultrasonic parameter values. Typically, cross grain and sound knots exhibit less dramatic signal differences compared to bark pockets, holes, splits, shake, decay, and wane.
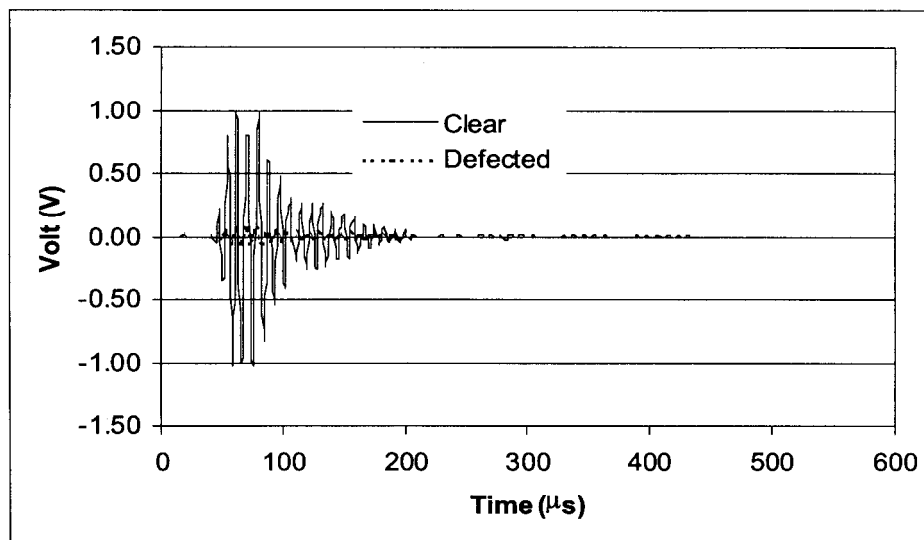

Figure 2. Comparison of received ultrasonic signal through clear and defected wood in unsound knot.
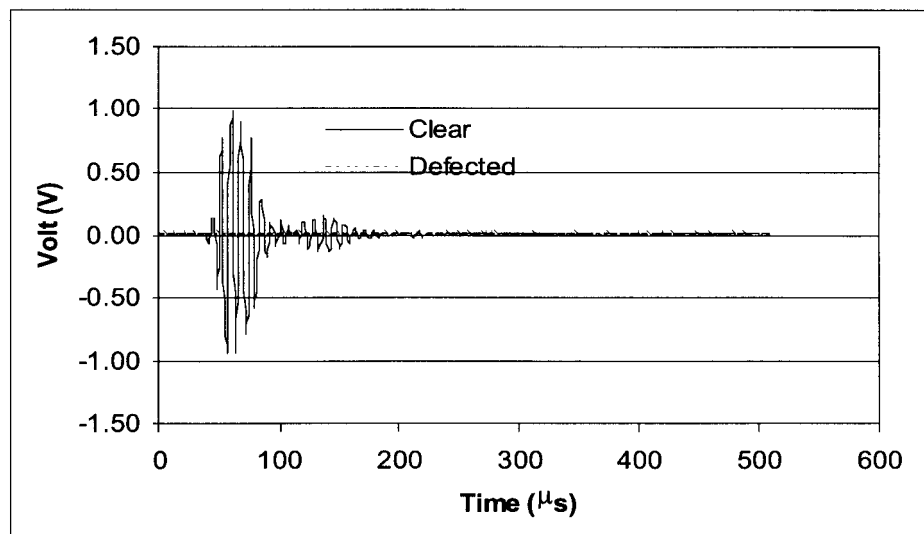
Figure 3. Comparison of received ultrasonic signal through clear and defected wood in bark pocket.
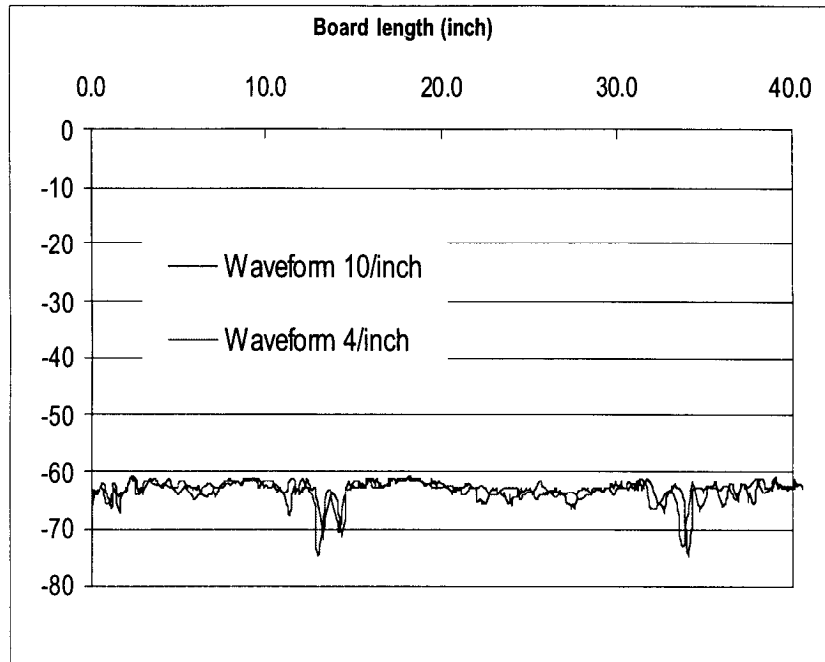
Figure 4. Energy/pulse values, collected at two scanning resolutions, are plotted along the board's length for sound knots on a yellow-poplar deckboard.
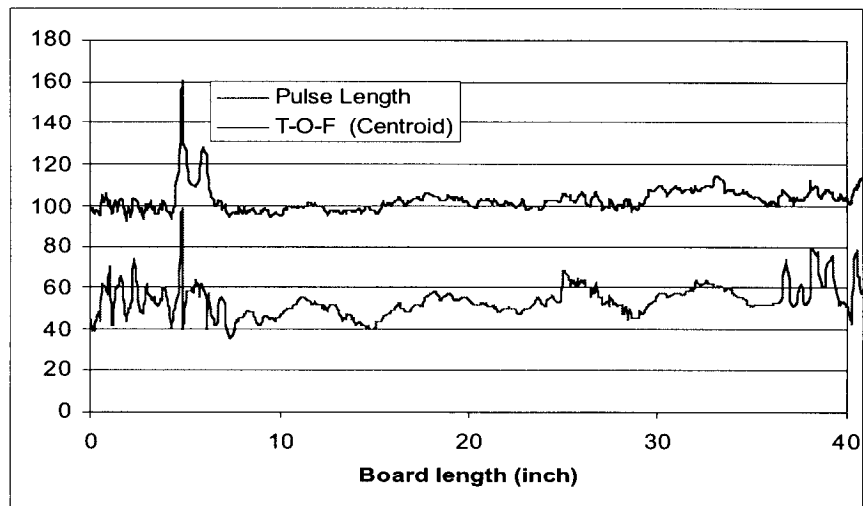

Figure 5. Pulse length and centroid time of flight (TOF) are plotted along board length for an unsound knot on a yellow-poplar deckboard.
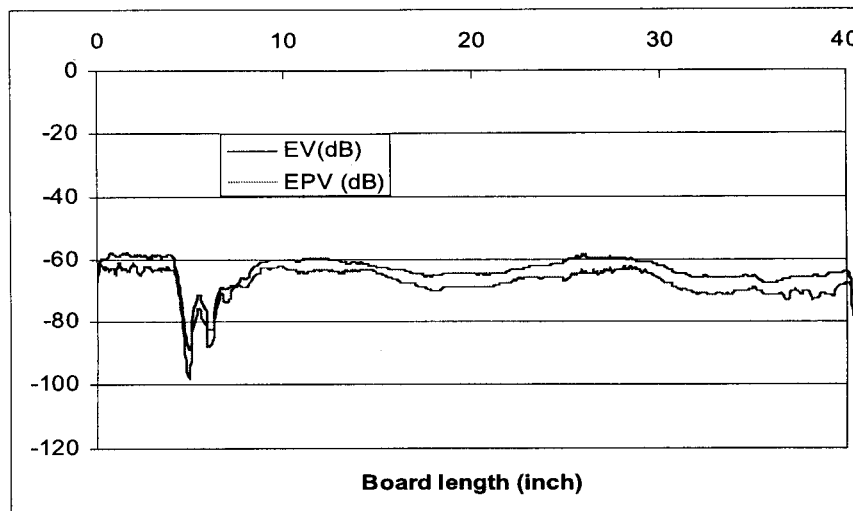
Figure 6. Energy values and energy/pulse values are plotted along board length for the same deckboard appearing in Figure 5.
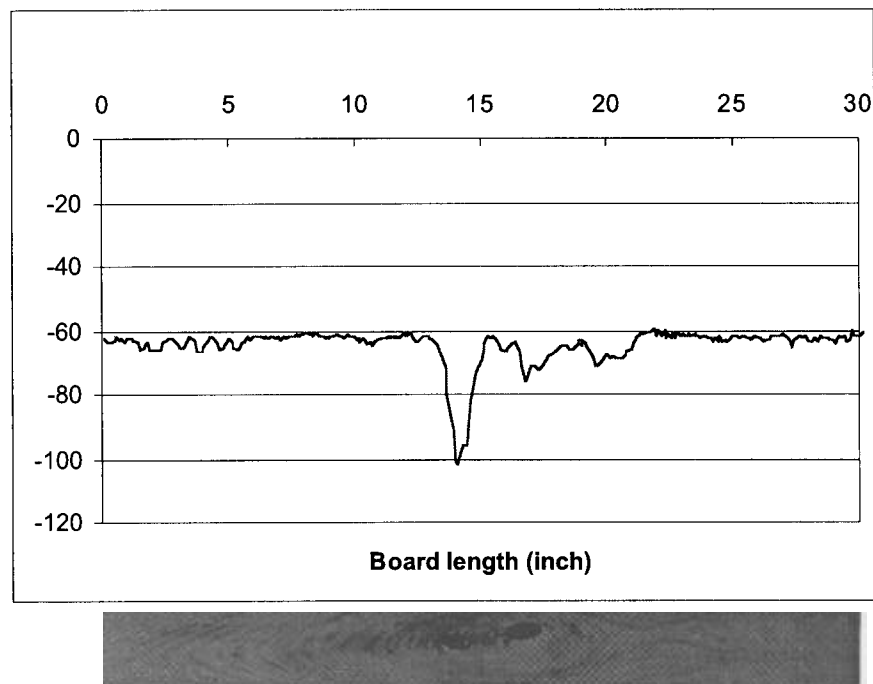

Figure 7. Energy/pulse values are plotted along board length for a hole on a yellow-poplar deckboard.

CONCLUSIONS

Rolling transducers are able to collect ultrasonic data for deckboards quite reliably. Measurements on multiple samples of the same defect, repeated measures of the same scan line, and measurements at different scanning
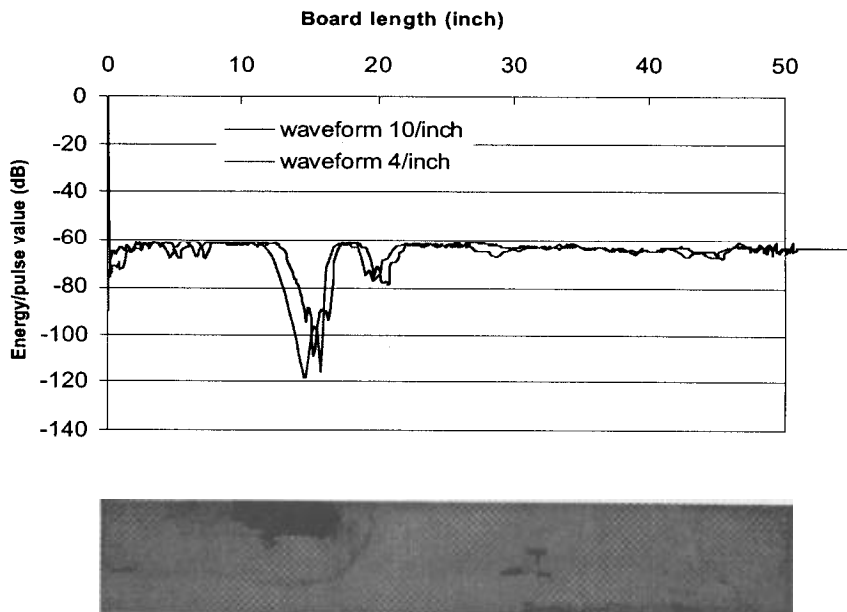
Figure 8. Energy/pulse values are plotted for decay on a yellow-poplar deckboard.

speeds all demonstrated consistent results. The use of rolling transducers eliminates the need for couplants (e.g., Vaseline, water), and so paves the way for on-line ultrasonic scanning.

A number of ultrasonic parameters were measured: energy, energy/pulse, pulse length, time of flight. In the case of each defect type, there is at least one parameter that is sensitive to that defect type. Sensitivity is defined as responding differently than the same parameter through clear wood. Still, multiple parameter signals will likely need to be used to identify a defect type uniquely. Subsequent research will investigate additional ultrasonic parameters and determine which combinations are most effective for each defect type.

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PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL HARDWOOD SYMPOSIUM

West Virginia Now—The Future For The Hardwood Industry?

EDITED BY

DAN A. MEYER
NATIONAL HARDWOOD LUMBER ASSOCIATION
MEMPHIS, TN

Canaan Valley Resort & Conf. Center
Davis, West Virginia
May 11-13, 2000

ACKNOWLEDGEMENT

These proceedings contain papers presented at the Twenty-Eighth Annual Hardwood Symposium. The results reported and the opinions expressed are those of the authors. NHLA assumes no responsibility for the content of these proceedings beyond reasonable acceptance for conformity to style.

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