Impact of nondestructive testing and evaluation of wood products

Robert J. Ross

Abstract The objective of this presentation is to highlight the significant contribution nondestructive testing and evaluation makes for manufacturers and users of wood products. Several widely used nondestructive testing and evaluation technologies are discussed. Examples, including the profiling of logs using laser technologies, veneer grading with ultrasound, lumber grading, and in-place condition assessment with a variety of technologies, are presented. Growth areas include the assessment of trees and the evaluation of historic artifacts and structures. The importance of the International Nondestructive Testing and Evaluation of Wood Symposium Series to the growth in the use of nondestructive testing and evaluation of wood is highlighted.

Keywords Nondestructive testing, evaluation, wood, wood products

1. INTRODUCTION

1.1. General information

The field of nondestructive testing and evaluation of materials is constantly evolving. This is especially true in the wood and fiber based materials area. For example, early research on nondestructive testing and evaluation technologies for wood products focused on methods to assess the performance characteristics of structural lumber in North America. Nondestructive testing techniques, equipment, and evaluation procedures resulted from those efforts that are now in widespread use. Today, worldwide research and development efforts are underway to examine the potential use of a wide range of nondestructive testing technologies for evaluating wood and wood-based materials—from the assessment of standing trees to in-place structures.

The original impetus for research in nondestructive testing and evaluation of wood was the need to provide methodologies for assessing wood-based materials and products so that more accurate decisions could be made on proper use. This is still the major driving force for NDT/NDE of wood research, with two significant additional challenges. First, there is an increased emphasis by publics around the world to address forest and ecosystem health issues. Utilization of woody biomass, for a variety of products, will play a key role in providing economical options for managing the health of these forests and ecosystems. Second, the marketplace has increasingly become global in nature. Shipments of raw materials and products between countries on different continents is now

commonplace. Both of these challenges will require accurate, cost-effective nondestructive testing and evaluation technologies. The international forest products research community is conducting nondestructive testing and evaluation research that is aimed at providing the technologies needed to address these challenges.

The objective of this paper is to highlight the significant contribution nondestructive testing and evaluation makes for manufacturers and users of wood products. Several widely used nondestructive testing and evaluation technologies are discussed. Examples, including the profiling of logs using laser technologies, veneer grading with ultrasound, lumber grading, and in-place condition assessment with a variety of technologies, are presented.

1.2. International Nondestructive Testing and Evaluation of Wood Symposium Series

The International Nondestructive Testing and Evaluation of Wood Symposium Series was initiated by Washington State University **and** the USDA Forest Products Laboratory (FPL). The first symposium was held at FPL in the fall of 1963, with proceedings produced and distributed in 1964. At the meeting, nearly 100 scientists, engineers, and industry leaders discussed the possibilities of a wide range of scientific means for testing wood nondestructively. The original goals of this series of symposia were to: 1. Provide a technical and scientific forum for researchers to present and exchange results from their latest research endeavors and 2. Bring researchers and industry together in an attempt to bridge the gap between the results of the researcher's efforts and utilization of those results by the wood industry. Sixteen symposia have been held to-date, with this being the 17th (Table 1).

Table 1 —Background information on the International Nondestructive Testing and Evaluation of Wood Symposium Series.

Symposium	Dates Held	Host Institution and Location
1	October 7-9, 1963	USDA Forest Products Laboratory, Madison, WI USA
2	April, 1964	Washington State University, Spokane, WA USA
3	April — May, 1970	Washington State University, Vancouver, WA USA
4	August 28-30, 1978	Washington State University, Vancouver, WA USA
5	September 9-11, 1985	Washington State University, Pullman, WA USA
6	September 14-16, 1987	Washington State University, Pullman, WA USA
7	September 27-29, 1989	USDA Forest Products Laboratory, Madison, WI USA
8	September 23-25, 1991	Washington State University, Vancouver, WA USA
9	September 22-24, 1993	USDA Forest Products Laboratory, Madison, WI USA
10	August 26-28, 1996	IBOIS-Chair of Timber Construction of the Swiss Federal Institute of Technology, Lausanne, Switzerland
11	September 9-11, 1998	USDA Forest Products Laboratory, Madison, WI USA
12	September 13-15, 2000	University of West Hungary, Sopron, Hungary
13	August 19-21, 2002	University of California, Berkeley Campus, CA USA
14	May 2-4, 2005	University of Applied Sciences Ebenwalde, Hanover, Germany
15	September 10-12, 2007	University of Minnesota Duluth, Duluth, MN USA
16	October 12-14, 2009	Beijing Forestry University, Beijing, P.R. China

Early symposia focused on basic NDE principles and efforts on lumber assessment procedures. The third symposium was devoted entirely to the Machine Stress Rating lumber grading process.
Symposia have attracted researchers and industry representatives from throughout the world. Recently, papers have been presented on new NDT techniques including those that focus on tomography, near infrared scanning, and innovative combinations of stress wave, laser and ultrasound techniques. A significant number of papers have been presented on assessment of trees and logs, with most work on lumber focusing on use of well-established techniques for evaluating species in Asia, Europe and South America.

1.3 Log Profiling

An excellent review of advances in log scanning and profiling technologies has been prepared by Szymani (2009). One of the best opportunities for maximizing yield when processing logs into lumber lies in the ability to accurately determine log shape and quality. Laser technologies, coupled with advanced computer modeling and simulation techniques, are widely used in many sawmill operations, providing full graphic displays for primary breakdown center operators to aid in critical cutting decisions. Equipment is available from several commercial firms.

1.4 Veneer Grading

The development and growth of the laminated veneer lumber (LVL) industry has been a direct result of the application of ultrasonic nondestructive evaluation methods for assessing the properties of wood veneer (Brashaw, 2002). Early research and commercial development focused on the use of speed of ultrasound wave transmission to evaluate veneer sheets. Individual veneer sheets were fed through opposing transducers that send and receive a wave. This wave travels longitudinally through the veneer. The time it took for the wave to travel between the transducers was referred to as the propagation time; using previously determined empirical relationships between propagation time and strength, each veneer was assigned to a specified strength category. Recent technical advances have coupled wave propagation times with other technologies to determine specific gravity, temperature, moisture content and modulus of elasticity of individual veneer sheets (Logan 2000). Metriguard, Inc. (Pullman, WA USA) is the only commercial manufacturer of ultrasonic veneer grading equipment. The first application of ultrasonic grading of wood veneer was reported on at the Fourth Nondestructive Testing of Wood Symposium (Kunesh, 1978; Logan, 1978). While originally developed and used for grading dry veneer, this technology has recently been expanded by some manufacturers for assessing green veneer as a means to better utilize materials (Brashaw and others 1996).

1.5 Structural Lumber Grading

Sorting lumber into classes for a specific end-use is termed "grading". Galligan and Kerns (2002) have prepared an outstanding summary of the history, and the current status of, lumber grading. By nature, lumber grading (visual or machine grading) is a nondestructive process. Starting with limited commercial ventures in 1963, the production of mechanically graded lumber exceeded 1 billion board feet by 1996. A variety of grading machines, that use several nondestructive testing techniques, are currently approved by the American Lumber Standards Committee Board of Review for grading structural lumber.
Results from many of the early research and commercial development efforts were presented at Nondestructive Testing and Evaluation of Wood Symposia. Technical information from these presentations has been captured and published in the symposia proceedings.

1.6 Delamination Detection

An excellent reference on the topic of delamination in wood, wood products, and wood-based composites has been prepared by Bucur (2011). This reference provides detail on the causes and mechanics of delamination, as well as an outstanding review of nondestructive detection techniques.
Results from one of the first studies aimed at using nondestructive testing to detect bond line defects in wood composite materials were presented at the Second Nondestructive Testing of Wood Symposium.

Suddarth (1965) reported on research designed to find a suitable technique for locating adhesive bond defects in the Polaris missile nose fairing using mechanical impedance measurements.'
A wide array of technologies, including non-contact ultrasound, forms the basis for equipment,that is currently used in production environments to monitor wood composite material manufacturing processes.

1.7 Structural Condition Assessment

Wood is used extensively for both interior and exterior applications in the construction of a variety of structures (residential, agricultural, commercial, government, religious). The deterioration of an in-service wood member may result from a variety of causes during the life of a structure. It is important, therefore, to periodically assess the condition of wood used in structures to determine the extent of deterioration so that degraded members may be replaced or repaired to avoid structural failure.
Assessment of the condition of wood in a building can be conducted for a variety of reasons. Code compliance, historic preservation, or alternative uses of a structure are frequently cited reasons for conducting a condition assessment. A structural condition assessment consists of the following: 1) a systematic collection and analysis of data pertaining to the physical and mechanical properties of materials in use; 2) evaluation of the data collected; and 3) providing recommendations, based on evaluation of the collected data, regarding portions of an existing structure that affect its current or proposed use. Such an assessment relies upon on in-depth of the wood members in the structure.
A wide variety of nondestructive evaluation techniques have been investigated for use in wood structural condition assessments. Visual, resistance drilling (probing), and stress wave or ultrasound-based techniques are all used either individually or in combination to inspect in-service wood. A practical review on these techniques is presented in Ross and others (2004).

CONCLUSIONS

Nondestructive testing and evaluation technologies for use with wood have evolved considerably in the past fifty years. Today, these technologies are used in an ever increasing range of situations —from the manufacture of lumber and wood-based composite products to the assessment of wood in historic structures. The impact of these technologies is significant and will continue to grow.

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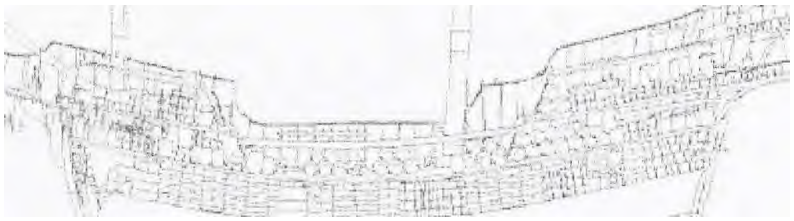
WOOD NDT



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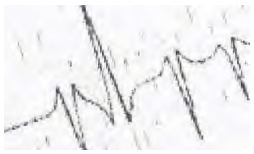

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