Internal Defect Detection Success Story: Industry Taps into the Forest Products Laboratory's Research Capabilities—So Can You

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Introduction

This presentation discusses a success story of cooperative research and development (R&D) and commercialization of ultrasonic detection technology for locating internal defects in lumber. The R&D work described in this paper is the result of a unique federal laboratory and private sector partnership between the USDA Forest Service, Forest Products Laboratory (FPL) and Perceptron, Inc., a manufacturer of scanning systems for the forest products industry. Efforts by research engineers at the FPL on applying ultrasonic nondestructive evaluation (NDE) methods proved successful in laboratory and industrial trials. As the industrial licensee, Perceptron is commercializing this technology and bringing it to the market place. This cooperative research and development project has expanded to cover a number of commercial forest products manufacturing applications. In addition, the presentation explains the various ways in which the private sector can tap into FPL's expertise and research capabilities.

Ultrasonic Nondestructive Evaluation (NDE) of Wood Quality

Under the principal direction of Dr. Robert Ross, the Forest Products Laboratory (FPL) has been involved in research aimed at developing a low-cost, industrial-type NDE detection system that identifies natural occurring and manufacturing caused internal defects in wood (e.g., logs, lumber, veneer). Ultrasonic NDE techniques are currently used in industry to grade wood veneer and inspect wood structures (Ross and Pellerin 1994). One of the underlying premises for ultrasonic NDE is that sound transmission characteristics are sensitive to various wood properties and features (e.g., strength, slope of grain, and defects like knots and surface checks) that determine the quality of wood products. Sensors, called transducers, are placed along opposite edges or faces of the lumber. One transducer transmits ultrasound into the wood, and the other receives the sound wave after it passes through. Ultrasound transducer pairs can be oriented in different directions to be sensitive to different board defects. As a result, splits, endchecks, and honeycomb (i.e., internal checking) are easily identified using ultrasonic NDE.

Internal Defect Detection Research and Development

The USDA Forest Service, Forest Products Laboratory (FPL), developed a prototype ultrasonic NDE system to identify internal defects in wood, conducted pilot studies, and is now developing this technology with an industrial partner, Perceptron for commercial applications. This process started when in response to industry's needs (Chang 1992; Holland 1992), FPL conducted a series of research studies using ultrasonic NDE techniques to identify defects such as wetwood (bacterial infected wood) and drying-induced internal defects (honeycomb and deep surface checks) in lumber. Results of initial investigations (Ross 1992) showed potential application for the forest products industry. A patent was issued to FPL for the application of ultrasonic NDE for identifying defect-prone lumber (Ross 1994).

Industrial Trials and Technology Transfer

Based on these encouraging research results, a prototype ultrasonic NDE unit was designed and constructed at FPL for a series of industrial pilot trials.

Technology Marketing Unit, FPL

John "Rusty" Dramm, Technology Marketing Unit (TMU), FPL was brought in to find suitable industrial cooperators for pilot trial testing, help expedite technology transfer, and develop prototype applications testing. Working closely with USDA Forest Service researchers and their customers, the Technology Marketing Unit is responsible for expediting technology transfer. It is responsible for marketing Forest Service-developed research and technology. Interaction between research and user is critical, and any measures to increase those opportunities are encouraged. Implementing technology through the use of partnerships and "hands-on" teamwork is efficient and cost effective.

Webster Lumber Company

Initial pilot trials were conducted in cooperation with Webster Lumber Company, Bangor, Wisconsin (Fuller and others 1994, 1995; Ross and others 1995). In the trials at Webster Lumber Company, the ultrasonic NDE system predicted wetwood and defect-prone red oak lumber accurately more than 70 percent of the time in the green lumber. For kiln-dried (KD) lumber, the prototype system was also able to detect both sound wood and the presence of drying defects (i.e., honeycomb and deep surface checks) with an accuracy of more than 95 percent in the KD red oak 4/4 lumber. Dramm (1997) reported the Webster Lumber Company trial results to the 1997 Wood Technology Clinic in Portland, OR. From these successful mill trials, technology transfer and commercialization was pursued. Further assistance was found at the Natural Resources Research Institute.

Natural Resource Research Institute

After the successful trials at Webster Lumber Company, Brian Brashaw, Natural Resource Research Institute (NRRI) was brought in to identify specific industrial applications. NRRI is a research unit of the University of Minnesota, Duluth, specializing in applied research and development resulting in product development and product and process improvement. As part of NRRI's "Forest Products Technology Advancement," a technology assessment and implementation program was developed. The objective of the program is to identify wood-based technologies with the potential to increase economic growth in the Upper Midwest and to assist with commercializing these technologies. One technology identified was the ultrasound-based NDE technique and equipment for hardwood lumber developed at the FPL. Brashaw also helped expedite commercialization by developing additional industrial contacts to further assist in technology evaluation and prototype applications testing for this NDE technology.

Jointly, NRRI and FPL coordinated a project planning meeting in October 1995. One objective of this meeting was to update key Wisconsin and Minnesota hardwood lumber manufacturers on the development of the technology and to identify specific industrial applications for implementation. The other objective was to partner with these companies to develop additional lumber trials to further develop these industrial applications and provide information to potential technology licensees. Attending industry representatives affirmed the commercial feasibility and implementation of the ultrasound technology for use on hardwood lumber. The primary applications suggested included the use of ultrasonic NDE technology for identifying wetwood (bacterial infection) in lumber prior to drying, locating closed end splits in green lumber and for scanning dry lumber for defects such as honeycomb and end splits. Each company agreed to participate in additional industrial trials.

Woodcraft Industries

Woodcraft Industries, St. Cloud, MN, provided dimension red oak lumber and edge-glued panels for

ultrasonic NDE inspection. Evaluation of this material at the FPL on the prototype scanning equipment showed that NDE could accurately identify material containing defects (honeycomb, end splits, knots and sections of delaminated edge-glue panels).

Rajala Veneer Company

A hardwood veneer flitch trial was conducted at Rajala's Deer River, Minnesota operation. The objective of the trial was to evaluate the use of ultrasonic NDE to identify defect prone green red oak flitches prior to slicing into veneer. The prototype FPL ultrasonic NDE equipment was used to evaluate the study flitches. The flitches were then sliced into 1/16-in. thick veneer. The veneer passed through a veneer dryer, defected at the outfeed and the type of drying defect noted. NDE successfully identify closed end checks that resulted in degrade after drying. After drying, end checks were more than twice as long than prior to drying. A potential yield increases of 1.3% was determined if NDE was used to identify end splits prior to veneer slicing.

Potential Industrial Applications

Based on the industry meeting and the industrial trials, specific industrial applications for implementation were identified for further consideration. Initially, applications considered included ultrasonic NDE technology related to identification of (1) defect-prone hardwood lumber prior to drying and (2) internal drying defects of hardwood lumber after kiln drying. The application of ultrasonic NDE technology is best suited for quality assurance applications, sorting defect-prone material from normal wood, and process control in secondary manufacturing (e.g., interface ultrasonics with computerized chop saw). Application to hardwood veneer flitch quality assessment was also investigated.

Dry Kiln Operations

Ultrasonic NDE technology could be used to sort defect-prone lumber (e.g., wetwood) from production. Sorting would allow for less conservative drying schedules for most of the production. Defect-prone lumber could be dried on a conservative schedule. The only alternative is to dry all lumber on a conservative schedule or risk substantial drying degrade. Sorting with the use of NDE technology could result in more efficient dry kiln use while reducing drying-induced degrade.

Quality Assurance

NDE technology could also be used in inspection. An inspection strategy may be useful to identify and remove lumber that contains drying defects before processing costs are incurred. For outgoing inspection, the producer could provide a guarantee of defect material or a percentage of defect-free material. For incoming inspection of kiln dried lumber from suppliers, NDE could be used to determine how much drying defect is present. This would help curtail unnecessary manufacturing expenses accrued in additional processing of lumber with internal defects (e.g., honeycomb).

Secondary Manufacturing

The greatest benefit of NDE technology is likely to be realized within the secondary manufacturing operations. Secondary processors also have the greatest opportunity to incur unnecessary cost through each additional operation where material with drying-induced defects is processed. A good application of NDE within secondary manufacturing might be a retrofit into existing computerized equipment, such as a computerized chop saw, to improve cutting yields. Material handling is already part of the system. It is a matter of fitting the rolling transducers to some air cylinders with optical positioning sensors and interfacing with the optimizing software. Another option is to incorporate ultrasonic NDE with manual chop saw operations. In this application, the system can be an excellent grade "assister," marking hidden

defects that graders struggle with.

Licensing FPL Technology to Perceptron

Janet Stockhausen, Patent Attorney, USDA Forest Service prepared the necessary documentation for patenting and soliciting a suitable licensee. She was instrumental in securing Perceptron as the licensee for commercialization. Perceptron's participation with the U.S. Forest Service in NDE technology is to develop commercial products based upon it. Perceptron specializes in process controls and instrumentation for the forest products industry and has special expertise in both laser based and ultrasonic technology. The next step in commercializing NDE technology was to determine how it could be integrated into various primary and secondary operations. Perceptron, TMU, NRRI, and the FPL developed a partnership with several industrial cooperators to further evaluate NDE applications.

Cooperative Research and Development

The FPL and Perceptron developed a number of Cooperative Research and Development Agreements (CRADA) to further develop specific commercial applications of ultrasonic NDE technology for various wood products markets and different stages in the production process. CRADAs offer two advantages to industrial cooperators: (1) Confidentiality and rights of first refusal to any potential subject matter generated under a CRADA and (2) CRADAs give cooperators (e.g., Perceptron) time to further develop the technology to a point where it can be brought to market and recoup development costs.

Under the CRADAs provisions, Perceptron designed and developed an engineering NDE scanning prototype for evaluating specific industrial applications. This scanning test bed located at he FPL, allowed for automated scanning of various wood materials and interacted with a computerized data acquisition system. The NRRI, FPL and Pennsylvania State University (PSU) combined on a study to evaluate the new system for identifying wetwood in green red oak. Ultrasonic scanning results compared favorably to previous research by the FPL. Additionally, laboratory testing of wood samples was completed by Roger Pettersen, FPL, and showed good agreement between the ultrasound parameters and the level of bacterial infection.

Commercialization Efforts Refined

To develop recognition by the Lake States forest products industry, Perceptron participated in an automated defect technology workshop sponsored by the NRRI in October of 1998. Dr. Mark Shafer presented an overview of ultrasound technology and how Perceptron is focusing their development efforts for hardwood lumber applications. Approximately 120 individuals representing more than 45 hardwood lumber companies attended the workshops. More recently, Perceptron has begun visiting the companies that attended this workshop through NRRI contacts. The goal is to bring these companies up-to-speed on the commercialization of the technology and to begin a dialogue aimed at how this equipment can enhance their operations.

Perceptron's initial plan with the licensed technology was to develop a product for the hardwood industry that would permit them to sort bacterially infected wetwood prior to kiln drying. The idea was to speed up the kiln dry schedules by separating out those boards that were susceptible to drying induced defects such as checking and honeycomb as a result of accelerated drying. From a technical standpoint this application would be fairly easy to implement; but it soon became apparent that the marketplace was not as interested in solving this problem as first thought. This lead to a closer working relationship between Bill Adams, Perceptron and Dramm, TMU to looking into the marketing side of technology commercialization and identifying important technical needs of the customer. The net result was that research and development was refocused in two other directions.

Green Lumber Application

On the green lumber side the focus shifted to scanning larger members, specifically, for grading and sorting green pine and hardwood cants for targeted applications. These application combine the licensed ultrasound technology with proprietary laser shape scanning products, such as its Lasar and Tri-Cam lines, that Perceptron already had on the market.

Development began under a Cooperative Research and Development Agreement (CRADA) with a cooperative study at FPL. Cants from two mill cooperators were evaluated using NDE ultrasonics. Ultrasonics successfully identified "good" cants with only minor, localized defects. Ultrasonics also identified poorer quality cants with extended regions of internal defects, of which most correlated to knot clusters, juvenile wood, or decay pockets. Cants were then sawn into flitches corresponding to the path of ultrasound beam and evaluated. There was strong correlation of exposed features and ultrasound readings; some features, such as decay, were present but not visible to the naked eye.

With the successful test of the cant scanning, ultrasonic NDE was incorporated into Perceptron's cant-grading system. The cant-grading system is designed to inspect cants in-line prior to Tri-cam scanning. The system correlates the ultrasonic data to laser scanning dimensional data and visual assessment. All of this data is integrated with Perceptron's cant optimizing software as grade input. Direct comparison of ultrasound evaluation with external visual features showed excellent correlation of knots and energy transmission. The system provides integrated cant optimization by automatically detecting and classifying cant defects such as knots, grain distortion, and decay pockets.

Dry Lumber Application

On the dry lumber side the objective now is to commercializing products to assist hardwood mills detect internal defects, such as splits, checks, rot and honeycomb, in boards as they are processed. Called the CSR, Perceptron's system functions on a stand-alone basis scanning and marking defects to assist inspectors in making grading or cutting decisions. The system can also be tied directly into multi-parameter optimizing equipment, such as Barr-Mullin's Cell Scan, to provide data on internal features of concern that would otherwise go undetected.

Beyond these current product initiatives is a universe of other applications that differ by the wood material to be scanned and by the nature, size and location of the internal defects and other conditions affecting the disposition of the wooden member. The ultimate objective in each case is to provide customized NDE systems to enable sawmill operators to maximize returns on their raw materials and capital investment.

Ultrasonic NDE technology has shown strong promise in industrial applications for use in detecting internal defects in wood. There are many other potential applications in both the softwood and hardwood industries. Development and commercialization has shown that ultrasonic NDE technique developed by the FPL is nonintrusive and a reasonable approach to meeting the needs of industry. Response by the forest products industry to ultrasonic NDE technology has been positive. Success would not have been possible with out the unique public/private partnership between FPL and Perceptron in moving this Forest Service developed technology into commercial use.

How Can You Tap Into Forest Products Laboratory Research Capabilities?

FPL is aggressively and continually making improvements to integrate research, development, and technology transfer with its customers. FPL's key to success is to work through cooperative partnerships with industry and others. Cooperative "hands-on" teamwork is necessary to accomplish effective technology transfer moving research from the laboratory bench to commercially available technology. It is fundamental that a joint, closely cooperative team effort fully involves users, to transfer technology and solve problems.

Under technology transfer laws passed in the 1980's, Federal laboratories are encouraged to work with industry to more effectively transfer technology to the marketplace. Under these laws, the Federal researcher can patent their inventions providing intellectual property protection. With this protection, innovations can be licensed to encourage commercialization by the private sector. These laws also provide for private/public cooperative research and development such as being used in the developing ultrasonic NDE technology.

In addition to CRADAs, a number of other agreements can be used depending upon the interest of the parties, available laboratory equipment, research capabilities, funding sources, and so forth. The FPL and other Federal laboratories are very interested in working directly with industry to more effectively transfer their technology to the marketplace. The flexibility of these various agreements allows the industrial cooperator and the Federal government to craft an agreement that reflects the common goals of the parties. Universities are also frequent partners in these agreements. Agreements can be drafted for a number of parties to cooperate to solve a focussed problem. These arrangements can greatly leverage an individual party's funding and research resources.

For More Information

For more information on cooperative research and development or patents and licensing, contact the State & Private Forestry, Technology Marketing Unit, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398. Phone: (608) 231-9504; Fax: (608) 231-9592; e-mail **jdramm/fpl@fs.fed.us.**

In addition to working cooperatively with the FPL on research projects, a number of other resources are available to industry. A number of forest products research reports are available online at FPL's Website. Currently, there are over 1300 publications available online. Check out the FPL's homepage at **www.fpl.fs.fed.us/.**

Each year FPL sends out more than 100,000 publications and reports. Hardcopies of more recent publications are available from the FPL Publications Group. Requests for publications should be directed to Publications Group at (608) 231-9248. For general inquiries, please call the general FPL phone number at (608) 231-9200 or mail to the address above.

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