# Using sound to evaluate standing timber

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## INTRODUCTION

Our forests are an extremely valuable resource. In addition to their aesthetic and recreational value, forests serve as a renewable source of raw material for an ever-increasing list of wood and fibre products. Nature's engineering of wood through genetics, the environment and responses to Man's interventions creates a wide variability in wood as a material. Consequently, manufacturers and users of wood products are frequently frustrated in dealing with the forest resource. Manufacturers sometimes argue that wood is difficult to consistently process into quality products because of the wide range of properties that exist in the raw material. Users of wood products can be equally frustrated with the performance variability found in finished products.

Nondestructive evaluation (NDE) technologies have contributed significantly toward eliminating the cause of these frustrations. By definition, NDE is the science of identifying the physical and mechanical properties of a material without altering its end-use capabilities and using this information to make decisions regarding appropriate applications. Various technologies, including those that utilise x-rays, chemical analyses, vibration properties and sound wave transmission characteristics, are used to assess wood products nondestructively. In the forest products industry, NDE technologies have been developed and are currently used in lumber and veneer grading programs that result in engineered materials that have well-defined performance characteristics.

Currently, there is a strong interest in the development and use of a variety of NDE technologies to aid in the evaluation of standing timber. One NDE technique, which uses sound wave transmission characteristics, has received considerable attention as a possible tool to aid in evacuating the quality of wood in standing timber. The objective of this note is to describe briefly the principle of sound wave based NDE technology and highlight some current research activities that use this technology to evaluate trees.

## SOUND WAVE NDE

An in-depth examination of sound wave NDE technologies and its use with wood products is included in Ross and Pellerin (1994), Two fundamental material properties are commonly measured when using sound wave NDE technologies. Speed-of-sound transmission is a frequently used parameter that correlates well with various wood properties. It has been shown, for example, that the speed at which a wave travels in wood is dependent upon fibre (grain) angle and is influenced significantly by the presence of certain types of decay or deterioration. Sound wave attenuation (or the rate at which a wave loses energy as it travels through wood) is another parameter that correlates with wood properties. These two parameters can be obtained through the use of a variety of testing techniques and commercially available equipment.

## DECAY AND DEFECT DETECTION

A series of studies designed to investigate the use of sound waves to detect decay and resulting defects in trees have been conducted by various researchers (Combe *et al.* 1996, Curtu *et al.* 1996, Mattheck and Bethge 1993, Sandoz 1994, Yamomoto 1998). In general, they found that it is possible to locate large decay pockets or splits and cracks with current commercially available equipment. These efforts revealed that the speed at which a wave travels across the diameter of the stem of a tree is a good indicator of the presence of decay. It has been found that the apparent speed at which a wave travels in deteriorated stems is significantly lower than that for solid non-deteriorated stems. This has been shown for a variety of hardwood and softwood tree species from various sites throughout the world.

## WOOD PROPERTY ASSESSMENT

Several studies have been completed that were concerned with the use of sound wave technologies to assess the mechanical properties of wood in standing timber (Kodama 1992, Nanami *et al.* 1992a, 1992b, 1993). The test set-up for these studies was significantly different from that used for decay detection in trees. In these studies, a wave was induced into the tree in such a manner so that it flowed primarily along the tree stem. Accelerometers were placed approximately 0.5 m apart along the stem's primary axis, with the upper accelerometer being 1.0 m above groundline. A stress wave was induced into the stem by an impact hammer via a nail inserted into the stem. It was hypothesised that the characteristics of the resulting wave would be related to the mechanical properties (modulus of elasticity) of lumber and timber obtained from the tree. These research studies showed that a useful relationship does exist.

## CURRENT U.S. RESEARCH AND DEVELOPMENT EFFORTS

As part of an effort to develop technologies to assist land managers in assessing forest ecosystem health and to utilise undervalued small stems, the USDA Forest Service has initiated a series of studies with various cooperators to investigate use of NDE technologies for standing timber. As shown in Table 1, studies include a broad range of species covering a wide range of forest ecosystems. Although just beginning, the preliminary results from several of these studies are very encouraging. We have, for example, observed a very good correlation between sound transmission characteristics and the presence of decay in small-diameter balsam fir trees. To investigate sound wave technology for use in estimating wood properties, we conducted a study with fertilized Douglas-fir trees. We placed two accelerometers approximately 1.5 m apart along a stem, with the upper accelerometer about 2.0 m above ground level. A stress wave was introduced into individual stems by a set-up similar to that described above. It was found that the angle between the nail and stem should be less than 45 degrees. A good relationship was observed between sound transmission characteristics of these trees and the mechanical properties (bending modulus of elasticity) of structural lumber obtained from them.

TABLE 1 *Studies with various cooperators to investigate use of NDE technologies for standing timber*

| Location | Species | Cooperator |
|---|---|---|
| Alaska | Sitka spruce, Western hemlock | USDA Forest Service Pacific Northwest Research Station, Michigan Technological University |
| Arizona | Ponderosa pine | Michigan Technological University |
| Idaho | Douglas fir | University of Idaho |
| Michigan | Red pine | USDA Forest Service North Central Research Station, Michigan Technological University |
| Minnesota | Aspen, balsam fir | University of Minnesota, Duluth |
| Pennsylvania | Red maple | Pennsylvania State University |
| Washington | Douglas fir | USDA Forest Service Pacific Northwest Research Station, Michigan Technological University |

We plan to implement results of these studies through forest managers in the belief that techniques such as these will become an integral part of forest management practices.

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