Nondestructive evaluation of veneer quality using acoustic wave measurements

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Abstract Two nondestructive evaluation methods, impact-induced stress wave techniques and ultrasonics, were investigated to detect lathe checks and knots in veneer, which were identified as key veneer quality properties for some engineered applications. Measurements included wave velocity and attenuation in the directions parallel and perpendicular to the grain. The results showed that both techniques were sensitive to lathe checks when using wave propagation perpendicular to grain. For wave transmission parallel to grain, signals showed some sensitivity to knots. There was no significant difference in wave velocity measurements between stress wave and ultrasonic techniques. Regression models based on stress wave velocities in these two orthogonal directions were developed to estimate the veneer quality index giving a coefficient of determination ranging between 0.39 and 0.50.

Introduction Veneer quality is critical to the performance of veneer, wood-based composites such as plywood, laminated veneer lumber (LVL) and laminated veneer panels. Veneer properties affecting the quality of these products may be classified as originated from a) manufacturing processes, such as lathe checks, surface roughness, thickness deviation, and moisture content and from b) natural wood variability, such as knots, splits, density variation, grain angle, species, and growth ring thickness.

In some engineered applications, plywood and laminated veneer panels are subjected to bending stresses as planks or panels where shear (rolling or planar) failures in crossbands may govern their load-carrying capacity. For example, rolling shear strengths are important for stress skin panels, concrete forms, and low span-depth ratio decking members.

Rolling shear failure is significantly influenced by lathe checks in crossbands of plywood (Chow 1970, Palka et al. 1977). Chow (1970) found that by eliminating lathe checks in veneer, which was accomplished by using a saw to slice the veneers,
the rolling shear strength increased more than 2.5 times. The relationship between lathe check depth and shear strength was also found (Chow 1970). Another study also found that shear strength of LVL was significantly affected by loose veneer with deep lathe checks where the ultimate average shear strength of laboratory LVL was 1.7 times of commercial LVL with deep lathe checks (Bohlen 1975).

Knots are another common natural defect degrading veneer. Several studies showed that in plywood and laminated veneer panels, knots are affecting rolling shear much stronger than density, which usually dominates mechanical properties of clear wood. The rolling shear properties were affected by the presence of relatively large areas of knots (knotholes) in the parallel plies compared with those in the perpendicular plies (Palka 1966, Palka 1970, Palka et al. 1977, Hettiarachchi 1990). Detection of knots using acoustic waves propagating in the parallel to grain direction has been well researched. The impedance of knots to acoustic wave transmission was evidenced by a distortion in the wave contour (June 1979; Gerhards 1982). Other nondestructive methods were also sensitive to knots, such as X-ray methods and microwave methods.

By contrast, there is no reported research in the nondestructive evaluation of lathe checks. One challenge is that lathe checks are predominantly oriented parallel to the grain, therefore, a wave transmitted along the grain would not cross lathe checks, which suggests low or no sensitivity. Because of high attenuation of signals in the perpendicular to grain direction, this type of transmission was not considered in the past. However, with more sensitive acoustic equipment currently available, this option appears to be feasible.

Various acoustic methods were investigated for nondestructive evaluation (NDE) of wood products, which ranged from audio (approximately up to 20 kHz) to low ultrasonic frequencies (20 kHz to approximately 500 kHz). The impact-induced stress wave method (or stress method for short), using low audio frequency range (typically 1–5 kHz), has been extensively studied because of good signal transmission in wood and low cost of equipment. For example, a stress wave technique was studied to detect skips or voids in the gluelines of edge-glued red oak panels by measuring transit time and amplitude of waves propagating from edge to edge of the panel (Armstrong et al. 1991). Wave velocities were also used for detection of wetwood and biodegradation (Ross 1994, Ross et al. 1996). Similar techniques were studied to detect lumber drying defects, such as hidden honeycomb and closed surface checks (Fuller et al. 1995).

Advantages of ultrasonic methods include more controllable and repeatable wave input and higher resolution related to smaller wavelength (higher frequency). Ultrasonic techniques are also more feasible for on-line inspection than the stress wave method as it does not involve a cumbersome impact device, such as a pendulum. As a variation of ultrasonic testing (UT), the acousto-ultrasonic (AU) method has evolved as a combination of acoustic emission (AE) and UT. The AU approach uses transmission similar to typical ultrasonic pith-catch configuration but uses AE sensors, which generally operates in a low ultrasonic range, and uses signal processing methods similar to AE. Lower frequency associated with AU testing is more desirable for wood products because high frequency is rapidly attenuated. AU techniques have been successfully used to monitor curing process, assess cured adhesive bonds in parallel wood laminates, and detect knots (holes), decay, splits, and cross grains, and panel quality (Beall 1993; Beall et al. 1993; Biernacki et al. 1993; Lemaster et al. 1987; Lemaster 1993).

The objectives of this research are to investigate: a) sensitivity of stress wave and AU methods in the directions perpendicular and parallel to grain to detect