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The reduction in errors associated with ultrasonic non-destructive testing of timber arising from differential pressure on and movement of transducers

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Abstract

Timber is a valuable structural material to construction and other industries. The trees which are its source have also environmental value which make its conservation obligatory. Due to its organic origins control of material quality is primarily retrospective. This makes its structural behaviour difficult to predict. Material status is further diminished where test regimes used to predict structural behaviour are inexact. Such deficiencies have been identified when testing timber with the ultrasonic contact method. A differential pressure applied to and movement of ultrasonic transducers during testing is cited for causing fluctuations in transmission time readings and pulse velocity data calculated from it. Two mechanical units using hydraulic fluid were developed to restrict movement of and exert an equal pressure on a pair of 54 and 200 kHz transducers. Test results show a reduction in transmission time variations of on average 86.7%.

Keywords: Ultrasound; Timber; Decay; Conservation; Scan; Non-destructive

1. Introduction

The aim of non-destructive test regimes is to provide data on a specimens service characteristics, without reducing its ability to serve. The accuracy of data acquired from non-destructive tests will dictate the level of confidence attributed to material assessment.

Ultrasound has been used with significant success to diagnose and monitor medical conditions [2] and detect material disbonds, welding and fatigue cracks in metals [1]. Progress in ultrasonic non-destructive testing of timber however has been more tentative. Under investigation here is the method and process used to couple ultrasonic transducers to timber samples. The method and process used for holding and exerting pressure on transducers during transmission time readings is primarily manual. For manual operation of contact transducers during ultrasonic non-destructive testing of timber, fatigue and other physical constraints can, to varying degrees, have an impact on the operation being performed. It has been shown that errors arise due to differential pressure on and movement of contact ultrasonic transducers, this "can result in decreases in propagation time of up to 3.6 μs" [3]. Testing the effects of transducer pressure between 0 and 80 kg/m^2, Taylor et al. [4] states; "possible variation in applied pressure, would probably be between 15 and 65 kg/m^2. This resulted in a 1% change in velocity which suggests approximately a 6 mm increase in path length, which is unrealistic".

If transducers were orientated directly opposite each other and capable of being held in each hand of the same operative equal pressure could be maintained reasonably accurately (at least for a short period). However,

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this is not always possible and transducers may move, even if the same operative is able to hold both transducers. Transducer spacing may often necessitate holding by more than one operative.

The manufacturer of the instrument used in these tests provides a "set reference bar" stamped with its specific ultrasonic transmission time reading, in this case 26.3 μs (see Fig. 1). During calibration when both transducers are placed against the set reference bar, a knob on the instrument is rotated until the display reads 26.3 μs; the instrument is calibrated. An anomaly now presents itself because of zero transmission time fluctuation during calibration, even though hand pressure is used to hold transducers against the set reference bar (see Fig. 1). It is considered that material (as well as method and process) may impact on transmission time errors.

2. Procedure and method for manual tests

The primary ultrasonic process used for testing timber is pulse through-transmission [1]. The direct method shown in Fig. 2 is used in these tests. Using two transducers in direct contact with the timber, one transducer sends a signal which the other receives. The time taken for sound to reach the receiving transducer is recorded in microseconds. Transmission time data can be used with transducer spacing to obtain the pulse velocity, which is indicative of material characteristics. Where the speed of sound in a material is known this can be used with transmission time to obtain material thickness. This is not viable with timber due to high variations in the sound speed, even within the same timber species.

Manual operation is mainly used to connect transducers to timber samples. Coupling grease, to dispel air and improve acoustic contact, is applied to the face of each transducer which are then pressed against the timber sample. Applying pressure to the transducers dispels excess coupling gel into voids and excess from the edge of transducers. As pressure is applied to each transducer, the transmission time is recorded. At this point significant transmission time fluctuations make readings difficult to discern from the LCD display on the pulse generator.

3. Equalising pressure to transducers

A pressure equaliser device Mk I was developed to exert an equal pressure on and restrict movement of a pair of 54 kHz transducers. Tests were carried out to verify any improvement in accuracy of pulse data and to investigate an optimum testing pressure. Transmission time readings were taken longitudinal to the grain with a spacing of 650 mm between transducer faces.

A pressure equaliser device Mk II was then developed for use with a pair of 200 kHz transducers to further verify results. The Mk II pressure equaliser took transmission time readings perpendicular to the grain, being capable of a maximum spacing between transducer faces of up to 150 mm. Fig. 3 shows the transducers used in testing.

3.1. Pressure equaliser Mk I

Equal pressure on the 54 kHz transducers is achieved by using a hydraulic system, sealed against the ingress of air. Pressure is applied to each transducer by it's own hydraulic piston and cylinder acting on one end of a leaver with the transducers held at the other end (refer to Figs. 4 and 5).

Both hydraulic cylinders are connected by a length of hydraulic hose, permitting transducers to be used at a distance apart, limited only by the length of hydraulic hose. Equal pressure is obtained at each transducer because pressure in the hydraulic fluid is equal throughout the system and actuates symmetrical leaver arms, cylinders and pistons.

Pressure is generated by turning the pressure thumb screw against either or both hydraulic pistons (see Figs.

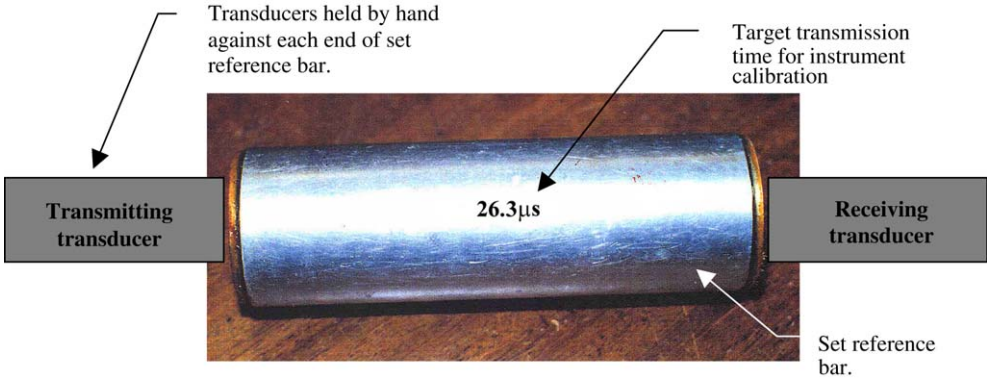

Fig. 1. Calibration of transducers by hand using manufactures set reference bar.