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Ultrasonic Tomography for Detection of Damage in Timber Beams and Ties

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Summary

The faculty and students in Texas A&M University's Zachry Department of Civil Engineering used ultrasonic tomography (UST) as a nondestructive testing tool in detecting damage in timber ties and beams commonly used in the railroad industry. Currently, the two main means of assessing the structural health of crossties include: visual inspection and use of a gage restraint measurement system. The quality of results from a visual inspection of crossties is highly subjective to an inspector's skill. While a standard testing procedure for assessing crosstie strength by asserting a lateral load on the rails over a specific duration of time, a gage restraint measurement system does not provide details about the location, type, and size of defects within the timber crosstie.

A UST acquisition device, MIRA A1040, was used to scan 12 various timber ties and beams. The laboratory scans showed promising results of detecting internal discontinuities such as cracks, decay, holes, and splits. However, there are some challenges with the shear waves penetrating the timber due to its porous nature. Using TAMU's test results, the following conclusions can be drawn:

- Full crosstie depth scans completed with a frequency of 50 kHz were able to be measured at a rate of 3 to 4 seconds per individual scan. In this laboratory trial, the process was quite slow due to the limited size of the device. The equipment could be sized to inspect an entire tie in a few seconds, making the device suitable for new tie inspections or spot field inspections.
- Shearing scans can be taken of the full depth of the beam and ties.
- Shear stress wave velocities in a healthy timber tie range from 3,600 to 4,200 feet per second; therefore, wave velocities propagating above or below this range could indicate damaged timber.
- Large cracks can be detected by the UST device
- Smaller flaws such as knots, splits, and holes are not yet able to be adequately detected due to the nonhomogeneous nature of the timber.

It was observed that the usability of the UST technique is affected by the wood's natural characteristics, which do not affect the timber's structural integrity, but do affect the shear wave pulse timing and strength, which agrees with timber research using UST devices.[1]

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INTRODUCTION

The occurrence of damage and deterioration in railroad timber beams and ties can lead to failure of railroad components and, in the worst case, derailment of a train. It is crucial to detect damage at an early stage so that, by taking appropriate measures, failure can be prevented.

This research investigated the use of ultrasonic tomography (UST) to detect damage in timber beams and ties.

UST Technology

The UST technology consists of using a 4-inch by 12-inch array of ultrasonic transducers that generate shear waves through the depth of the timber specimen under the transducers. Figure 1 shows the MIRA A1040 UST device used in laboratory research conducted by TAMU.

Figure 1. UST Equipment: MIRA A1040

The shear waves generated by the UST are reflected by internal discontinues within the timber specimens. The waves are sequentially emitted and received by 66 paired transducers per single scan, which cause repeated reflections and patterns to stand out for inspections. Figure 2 shows the UST device signal transmission process.

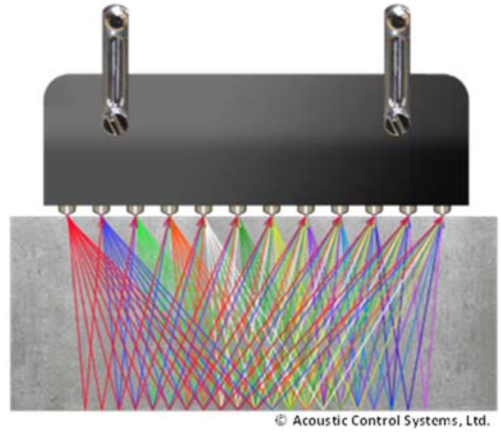

Figure 2. UST Signal Transmission

Through the use of dry-point-contact piezo-electric sensors, the transducers do not require the use of a coupling agent. The recorded signals undergo automated signal processing to identify the existence, location, and size of the potential discontinuities. Accompanying UST software is then used to map entire 3D images of the timber beams and ties.

Test Methods

In order to determine the practicality of this method for in-field testing, 12 timber ties were inspected using the UST device. The test matrix is shown in Table 1 and displays how many red oak, white oak, creosote treated, and untreated ties were evaluated.

Table 1. Timber Tie Test Matrix

	Creosote Treated, T	Untreated, U
White Oak, W	3	3
Red Oak, R	3	3

Figure 3 and Figure 4 display the timber ties that were used during the research throughout this project.

Figure 3. Untreated Oak Timber Ties

Figure 4. Treated Oak Timber Ties

A grid system was marked on each side of the timber ties in order to keep a corresponding record of the locations of flaws. The UST transmitted the shear waves at a frequency of 50 kHz. The average of five random velocity measurements, taken at multiple locations along the ties, was used for the fixed velocities in the map scans of the ties. A horizontal step increment was taken at 6 inches in the direction parallel to the long dimension of the UST device and 2 inches in the direction perpendicular to the long dimension of the UST device while collecting data in the mapping mode of the UST. Figure 5 shows a schematic of the test setup.

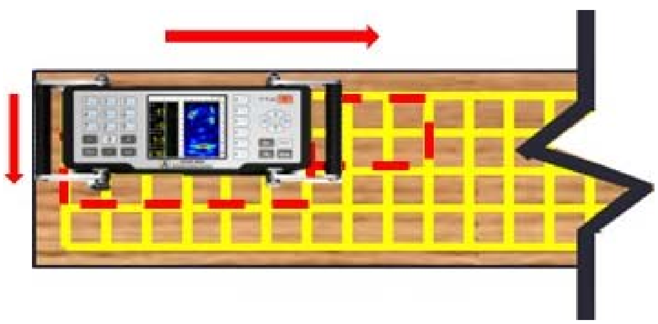

Figure 5. UST Testing Setup

Field Test Results

The first findings of the research led to determining the average velocities of the four types of timbers: red oak untreated, red oak creosote treated, white oak untreated, and white oak creosote treated. Table 2 summarizes the velocities of the timber ties.

Table 2. Velocities of Timber Ties

	Treated	Untreated
	(ft/s)	(ft/s)
Red Oak	4,134	3,937
White Oak	3,675	3,963

Once all of the scans were taken of the timber ties, the scans were stitched together with the other scans within a map to generate a three-dimensional figure of the beam. Two-dimensional cross sections (B-scans) are able to be viewed within the three-dimensional scan.

Figure 6 shows an image of the treated white oak specimen and three B-scans taken 2 inches apart (e.g., at 2, 4, and 6 inch depths from tie surface).

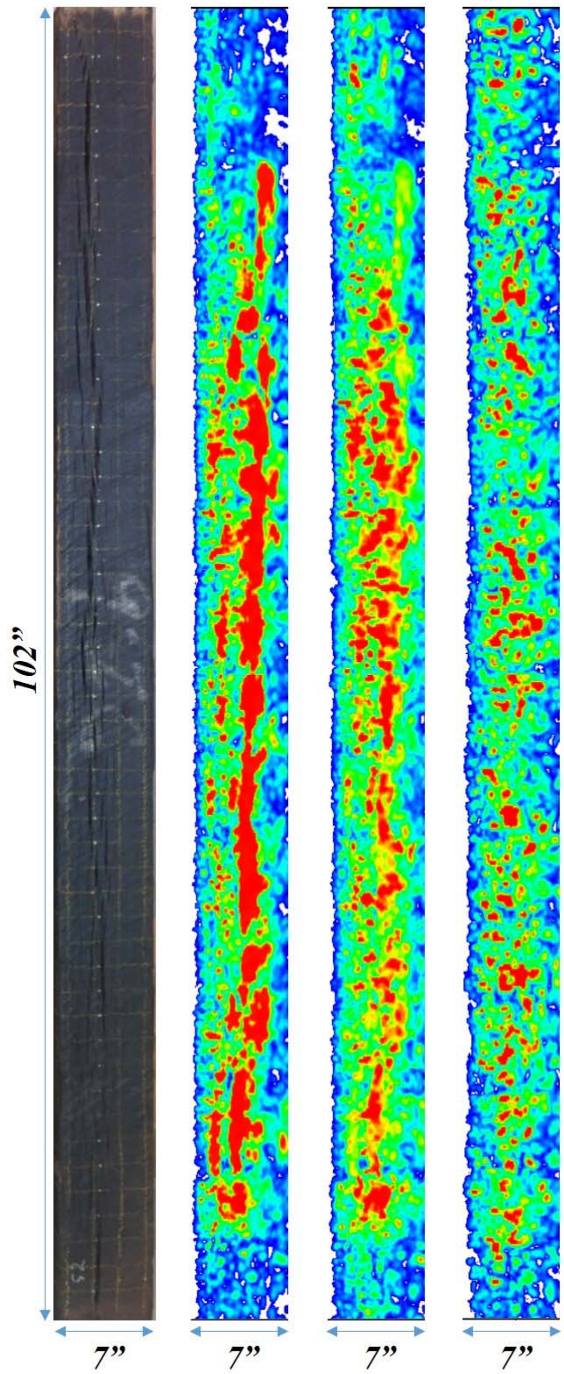

Figure 6. Treated White Oak Tie and B-Scans

In Figure 6, the transition of colors in the B-scans represents a transition in material properties. It should be noted that in the treated white oak specimen, there is a large split of the tie at approximately mid depth of the tie from one end of the tie to the other, and in all three of the B-scans of the specimen, the color changes from a blue tinted green to red at approximately the same level within the specimen as the split.

The shear waves transmitted by the UST require a solid medium in order to propagate. Due to the inhomogeneous nature of timber ties and beams, it can be difficult for the shear waves to propagate the full depth of the specimen.

In some cases, the B-scans taken by the UST indicated areas of possible discontinuity where there were no apparent discontinuities upon visual inspection. This could be a result of knots, changes in the grain pattern, or other such characteristics within timber that have different material properties than that of the surrounding timber.

CONCLUSIONS

UST was successful in detecting large discontinuities within timber ties from one side. However, due to the inhomogeneous nature accompanied with timber, it had difficulty detecting small discontinuities such as knots and small cracks within the timber ties. It was concluded that average velocities for the measured red oak and white oak timber ties ranged from approximately 3,600 ft/s to 4,200 ft/s. If a tested timber exhibited a shear wave velocity greater than or less than that of the expected range, there is reason to suspect potential deterioration. However, this velocity range is not representative of timber ties made from other varieties of wood. The effect of shear wave velocities on creosote was inconclusive, because timber is a natural product with a large variation in material properties.

FUTURE WORK

To increase the reliability and repeatability of the results, the following future work is recommended:

- Slice along the length of the timber to allow for an exact comparison of a B-Scan.
- Use the UST to scan ties made of other varieties of wood.
- Further investigate the effect of the creosote (or other preservative) treatment on the shear wave velocities.
- Introduce an ultrasonic longitudinal wave transducer that emits waves which can travel through solid, liquid, and air.
- Conduct laboratory testing of ties that are deemed deteriorated and in nonworking condition. Then, compare B-scans from the structurally unsound ties to the B-scans of ties used in this research.
- Conduct in-track inspection of ties to assess the effects of tie plates and fasteners on the inspection. Also, assess the effects of boundary conditions (e.g., ballast quality and support)
- Increase the number of samples by which to take UST measurements.
- If continued studies prove UST is promising in timber crosstie inspection, adapt the scanning device to use on a mobile railcar system with increased scanning speed.
- Compare the UST results from future track testing to gage restraint measurement system results from the same track for the evaluation of UST success.

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