Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 09, Issue, 03, pp.26396-26400, March, 2019

ORIGINAL RESEARCH ARTICLE

OPEN ACCESS

INFLUENCE OF THE TRANSDUCERS POSITION ON ACHIEVING ACOUSTIC TOMOGRAPHY OF WOOD LOGS

[*1]Carrasco, E.V.M., [1]Bremer, C.F., [2]Alves, R.C., [3]Julio, E.R. and [4]Mantilla, J.N.R.

[1]Federal University of Minas Gerais, School of Architecture
[2]Federal University of Espirito Santo
[3]Federal University of Minas Gerais, School of Engineering
[4]Fumec University. Faculty of Engineering and Architecture

ARTICLE INFO

Article History:

Received 24th December, 2018
Received in revised form
28th January, 2019
Accepted 26th February, 2019
Published online 31st March, 2019

Key Words:

Non-destructive testing,
Tomographic imaging,
Decayed wood.

ABSTRACT

This paper deals with the determination of cross-sectional pieces of wood using acoustic tomography by means of the physical principle of emission and acoustic waves path. In order to evaluate this method three wooden samples were tested with the Acoustic Tomography Arbor Sonic 3D equipment. The objective was to verify the influence of the arrangement of the transducers in diametric portion of the logs and along its longitudinal direction, through the quality of information provided on its phytosanitary status. A visual analysis of the images generated by the software and subsequently an overlay of the imageswere made and the overlapping images were compared to the photographic images. The results showed a variation of images according to the arrangement of the transducers in the diametral portion and the overlapping provided a representative image of the real state of the logs. Regarding the arrangement along the longitudinal axis, it was possible to determine the phytosanitary status of the entire log. It was possible to conclude that the position of the transducers influences the acoustic tomography quality and that the proposed method enables to determine a more robust image to assess the levels of degradation of the wooden parts.

Citation: Carrasco, E.V.M., Bremer, C.F., Alves, R.C., Julio, E.R. and Mantilla, J.N.R. 2019. "Influence of the transducers position on achieving acoustic tomography of wood logs", *International Journal of Development Research*, 09, (03), 26396-26400.

INTRODUCTION

Forests are an extremely valuable resource for humans. The internal decay of trees threatens the health of forests and reduces the quality and added value of wood. The detection of this deterioration in trees is important not only for forest management, but also for public safety in urban communities. Early detection of internal decay in hardwoods can provide a significant benefit to the industry in terms of making accurate assessments of quality and volume estimates and resource use. It can also help foresters in prescribing silvicultural treatments to improve decision-making and management, thus helping to maintain a healthy forest (Wang *et al*., 2009). The method of stress waves has been widely recognized as a non-destructive, robust inexpensive technique for evaluating the internal structure of living trees and the wooden structure. The transmission time of the stress wave increases dramatically in damaged areas and internal defects can be detected by the difference between the measured time and the reference value (Pellerin and Ross, 2002, Chimenti, 2014). There are several commercially available accessories to perform stress waves tests to measure path-time of these individual waves in timber. However, some acoustic tomography equipment (for example, 2D ArboSonic, Picus Sonic tomograph and Arbotom) have been developed to produce and measure stress wave "multipath" in trees and construct two dimensional or three dimensional scans of a tree cross section. The principle of operation is simple, Figure 1: *i) several sensors are placed around the trunk, which are coupled to the wood by steel nails; ii) each sensor is tapped by a hammer; iii) the unit measures the travel-time of the sound wave generated by the hammer tap between each sensor; iv) if there is a hole, then the sound waves have to pass around the hole and therefore it requires more time to reach the opposite sensors*, Fakopp, 2012. A precise understanding of the velocity patterns of these waves in trees is important for the diagnosis of internal deterioration and is also required to develop an efficient imaging software to

***Corresponding author:* Carrasco, E.V.M**
Federal University of Minas Gerais, School of Architecture

analyze the internal deterioration of the tree or wood (Bucur, 2003). The application of this technology was first demonstrated using wood poles (Tomikawa *et al*. 1990) to inspect the internal condition of the poles. Later, many researchers have investigated the applicability of the technology to detect internal decay in living trees (Comino *et al* 2000; Devos and Szalai 2003; Gilbert and Smiley 2004; Wang *et al*. 2004b; Wang and Allison 2007; Allison *et al*. 2007; Deflorio *et al*. 2008; Lin *et al*. 2008, Nanami *et al*., 1992, Lawday and Hodges 2000, Rinn 2003, 2004 and Wang *et al*. 2004a).

Figure 1. Stress waves principle, Fakopp (2012)

So far, laboratory and field research applying acoustic tomography have been largely focused on urban trees with the main objective of ensuring the stability of trees to minimize the risk of falls and accidents. Deflorio *et al*. (2008) concluded that the incipient detection of deterioration in the periphery of the tree needs to be improved. Such techniques have proven to be effective not only in the green wood, but also to detect deterioration in antique wood (Lee and Oh, 1999). To improve the accuracy of deterioration detection, many researchers have studied the relationship between the mechanical properties of wood and the stress wave velocity (Wang et al., 2001a, Chauhan *et al*., 2005, Grabianowski *et al*., 2006, Alves *et al*., 2015). Dikrallah *et al*. (2006) presented an experimental analysis of acoustic anisotropy of wood, in particular the dependence of the velocity of propagation of stress waves in the principal axes of anisotropy in the cross section. They found a significant difference in terms of wave velocity, between waves propagating throughout the volume and directed waves in each transducer.

Maurer *et al*. (2005) studied the effects of anisotropy in travel time of the waves that allowed to perform tomography, assuming elliptical anisotropy and indicated that the velocity of the wave depends on the angle at which the transducer is placed and also on the anisotropic factor of the timber. Kazemi *et al*. (2009) found out that the ultrasonic velocities changed in different heights of the logs and in different directions. They also concluded that the ultrasonic velocity in the tangential direction was minimal, then it increased up to a maximum in the radial direction. Liang *et al*. (2010) showed that the velocity of the stress wave also increased as the number of annual growth rings increased. Gao *et al*. (2012) investigated the effect of temperature on the velocity of the acoustic wave in living trees and freshly cut stems, developing robust models to compensate these temperature differences. Measurements were carried out in different climates and seasons. According to Li *et al.* (2012) and Li *et al.* (2014), the potential of this technology has not been fully investigated, although studies on urban forestry using acoustic tomography proved to be efficient to detect moderate to severe internal decay within a log. The detection of the initial phase of this deterioration using this technology is still a challenge, due to the facts that *(1) the acoustic tomography techniques currently used are largely based on travel time measurements of acoustic waves, which limits accuracy and resolution of the obtained tomographic images; (2) the construction of acoustic tomography waves from traveling time is affected by the pronounced anisotropy of the tree species in terms of microstructure and properties of wood; and (3) interpretation of the scans is not a quantitative nature and often needs further confirmation or verification by other methods.* Considering that the quality of the scan depends on the number of travel time measurements of acoustic waves, the aim of this experimental study was to evaluate quantitatively the influence of the arrangement of transducers in diametric portion of the log and along its longitudinal direction, as well as the quality of information provided on the phytosanitary status of wood. The research approach was to overlapping several scans performed in a cross-section for a bi and three-dimensional tomography.

MATERIALS AND METHODS

For this study tree logs sectioned from different reforestation species collected in the Pampulha campus of the Federal University of Minas Gerais (UFMG) have been used. The tests were performed at the Nondestructive Testing Laboratory of the Structural Engineering Department at Engineering School. The samples had the characteristics described in Table 1.

Table 1. Characteristics of samples tested

Sample	Density (g/cm^3)	Height (cm)	Circumference (cm)	Shell thickness (cm)
1	0.58	40.5	124.0	1.0
2	0.59	54.0	77.0	1.0
3	0.47	27.0	121.0	1.0

For the tests the acoustic tomography of ArborSonic 3D equipment, with eight piezoelectric transducers, was used. The transducers were inserted, evenly spaced, in a cross section of the samples, using a rubber hammer, about 1cm deep. For each sample data in Table 1 were saved in the software. A metal hammer was hit three times in each transducer for generating sound waves. The ArboSonic 3D equipment measured the travel time of each wave with an accuracy of approximately 2 microseconds, and then transmitted the data via a USB cable to the computer. With the distribution of the internal sound in the log, the software calculated and generated a matrix of average velocities between the transducers, and from it, a velocity graph was created. From this graph, an image was generated with the representation of the phytosanitary status of the cross section of the log, highlighting the gaps, cracks, etc. The experiment was repeatedtwofurther times, varying the transducers positions along the same cross section, so that they reached different parts of that section. This change was made by rotating the transducers, each time, approximately 15º clockwise. Subsequently, the position of the transducers along the longitudinal direction of the log was changed. Six tomographic images were generated for each sample tested, each image represented a different position of the transducers. A visual analysis of the images was made and, with an imaging software, the three images of the same cross-sectional were rotated, so they matched the same position, followed by the overlapping of these images. After the overlapping, the images were compared with the corresponding photographic image as the position, size and shape of the defects. The degradation maps of the sections generated by the software were compared and the degradation levels in each section and in image were analyzed. For the analysis of the images variation along the longitudinal direction, the extrusion of images generated by tests performed on both cross sections of each sample was made.

RESULTS ND DISCUSSION

The generated images are represented by a range of colors ranging from green, when the timber is intact, blue, occurs when hollow, through red, which means the presence of deterioration. Figure 2 shows the representation in scale of each sample images generated by the transverse variation of the transducers in a section.

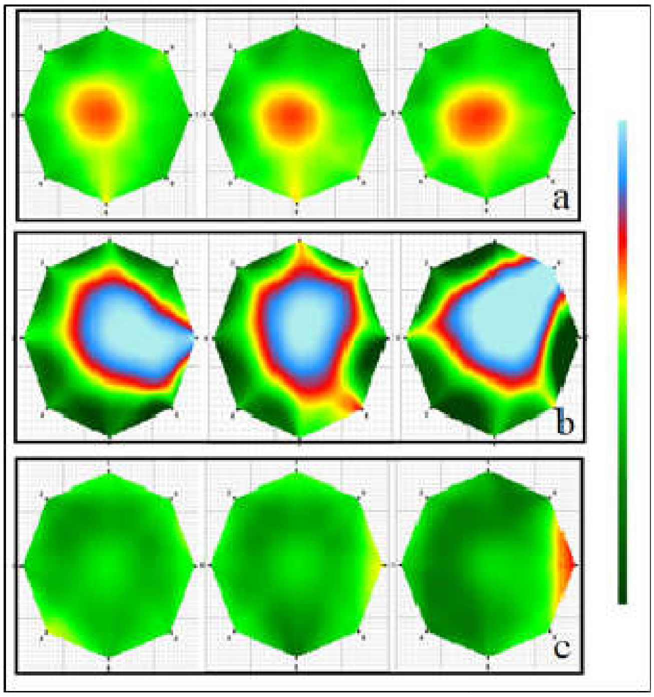

Figure 2. Tomographic images generated by the variation of the transducer in the transverse direction (a) Sample 1, (b) Sample 2 (c) Sample 3

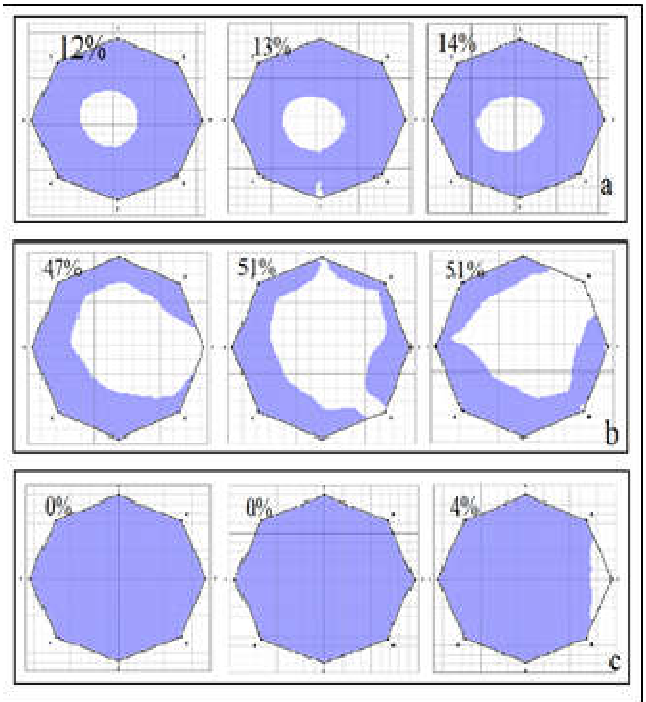

Figure 3. Degradation maps and their levels of degradation of a section (a) Sample 1 (b) Sample 2 (c) sample 3

Each image was generated by the transducers in different positions. It can be observed a subtle variation of the same section images, on the level of degradation. To analyze the level of degradation in each image, Figure 3 shows the map of degradation of images of the same sections shown in Figure 2, and the respective level of degradation percentage. It can be observed for all samples, a variation in level of degradation of a same section according to the variation of the position transducers. So, for a better comparison of tomographic images with photographic images, the tomographic images were treated in each section, trying to cover a greater level of detail of the sections.

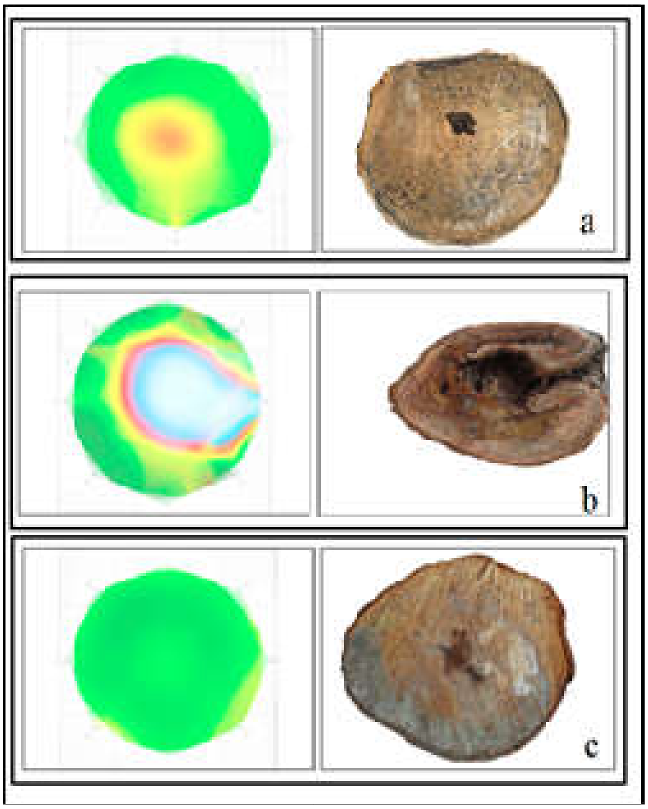

Figure 4. Superposed image and the corresponding photographic image (a) Sample 1, (b) Sample 2 (c) Sample 3

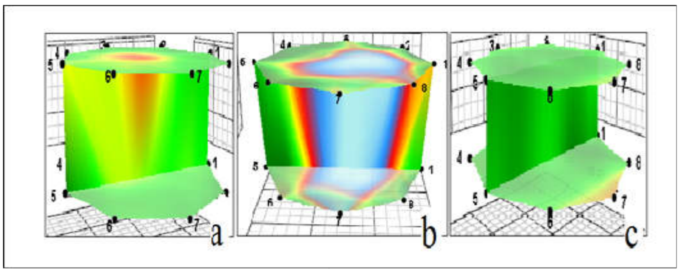

Figure 5. Extruded image (a) Sample 1, (b) Sample (2) and (c) Sample 3

Figure 4 shows the tomographic image treated with the corresponding photograph of each section. It can be observed a good level of detail. Figure 5 shows the extruded images of samples 1, 2 and 3.

Conclusion

The main conclusion of this work was that acoustic tomography is an efficient technique for non-destructive evaluation of the inner timber logs. The variation of the transducers positions in the transverse direction influences the tomographic image so that, the more changes in the transducers position, the greater is the level of detail obtained in tomographic images. Moreover, the variation of the transducers in the longitudinal direction of the log sections allows to evaluate the position, shape and extent of defects throughout the entire sample volume. The proposed method has identified hollow and small deteriorations in a very precise way, and also allowed well capture of the intact parts of the analyzed sections. The results of this and other future studies will be important in the art of diffusion, especially for the evaluation of living trees, identifying, if any, falls risks.

Acknowledgements

The authors would like to thank CNPq (Conselho Nacional de Pesquisa e Desenvolvimento Científico e Tecnológico), and FAPEMIG (Fundação de Amparo à Pesquisa do estado de Minas Gerais), for funding this research and UFMG (Federal University of Minas Gerais) for the infrastructure provided for the realization of the project.

REFERENCES

Allison, R.B., Wang, X., Ross, R.J. 2007. Visual and nondestructive evaluation of red pines supporting a ropes course in the USFS Nesbit Lake Camp, Sidnaw, Michigan. Proceedings of International Symposium on Nondestructive Testing of Wood, 15, Duluth, MN, USA, Forest Products Society, M. W.; pp. 43-48.

Alves, R.C., Mantilla, J.N.R., Bremer, C.F., and Carrasco, E.V.M. 2015. Application of Acoustic Tomography and Ultrasonic Waves to Estimate Stiffness Constants of Muiracatiara Brazilian Wood. *In BioResourses*. 10(1), pp. 1845-1856.

Bucur, V. 2003. Nondestructive characterization and imaging of Wood, Springer Publication, Berlin, 354 p.

Chauhan, S.S., Entwistle, K.M., Walker, J.C.F. 2005 Differences in acoustic velocity by resonance and transit-time methods in an anisotropic laminated wood medium. In Holzforschung. 59, pp. 428–434.

Chimenti, D.E. 2014. Review of air-coupled ultrasonic materials characterization. In Ultrasonics. 54, pp. 1804-1816.

Comino, E., Socco, V., Martinis, R., Nicolotti, G., Sambuelli, L. 2000. Ultrasonic tomography for wood decay diagnosis. Proceedings of International Symposium on Plant Health in Urban Horticulture, Braunschweig, Germany, pp. 279-290.

Deflorio, G., Fink, S. and Schwarze, F.W.M. 2008. Detection of incipient decay in tree stems with sonic tomography after wounding and fungal inoculation. In Wood Science and Technology. 42, pp. 117-132.

Devos, F. and Szalai, L. 2002. Tree evaluation by acoustic tomography. Proceedings of 13th International Symposium on Nondestructive Testing of Wood, Berkeley, CA, Forest products society, Madison, USA. Aug 19-21; pp. 339–349.

Dikrallah, A., Hakam, A., Kabouchi, B., Brancheriau, L., Baillères, H., Famiri, A. and Ziani, M. 2006. Experimental analysis of acoustic anisotropy of green wood by using guided waves. Proceedings of International Conference of the European Society for Wood Mechanichs (ESWM) and the Annual Meeting of COST Action E 35 , Florence, Italy, May 14-17; pp. 149-154.

Fakopp Enterprise Bt. Arbosonic 3D User's manual, 2012.

Gao, S., Wang, X., Wang, L. and Allison, R.B. 2012. Effect of temperature on acoustic evaluation of standing trees and logs: Part 1—Laboratory investigation. In Wood Fiber Sci. 44(3), pp. 286–297.

Gilbert, E.A. and Smiley, E.T. 2004. PiCUS Sonic Tomography for the quantification of decay in white oak (Quercus Alba) and hickory (Carya spp.). *In J Arboric* 30(5); pp. 277–280.

Grabianowski, M., Manley, B., Walker, J.C.F. 2006. Acoustic measurements on standing trees, logs and green lumber. In Wood Sci Technol 40; pp. 205–216.

Kazemi, S., Shalbafan, A. and Ebrahimi, G. 2009. Internal decay assessment in standing beech trees using ultrasonic velocity measurement. *In Eur. J. For. Res.* 128(4); pp. 345–350.

Lawday, G. and Hodges, P.A. 2000. The analytical use of stress waves for the detection of decay in standing trees. *In Forestry* 73; pp.447–456.

Lee, J.J. and Oh, J.K. 1999. Stress-wave technique for detecting decay in ancient structures. Proceedings of the Eleventh International Symposium on Nondestructive Testing of Wood, pp 161–167

Li, G., Wang, X., Feng, H., Wiedenbeck, J. and Ross, R.J. 2014. Analysis of wave velocity patterns in black cherry trees and its effect on internal decay detection. In Computers and Electronics in Agriculture 104; pp. 32–39.

Li, G., Wang, X., Wang, L. and Alisson, B.R. 2012. Acoustic tomography in relation to 2D ultrasonic velocity and hardness mappings. In Wood Sci Technol 46; pp. 551-561.

Liang, S., Fu, F., Lin, L. and Hu, N. 2010. Various factors and propagation trends of stress waves in cross sections of Euphrates poplar. *In For. Prod. J.* 60 (5); pp. 440–446.

Lin, C.J., Kao, Y.C., Lin, T.T., Tsai, M.J., Wang, S.Y., Lin, L.D., Wang, Y.N. and Chan, M.H. 2008. Application of an ultrasonic tomographic technique for detecting defects in standing trees. *International Biodeterioration and Biodegradation* 43: p. 237–239.

Maurer, H.R., Schubert, S.I., Bachle, F., Clauss, S., Gsell, D., Dual, J. and Niemz, P. 2005. Application of nonlinear acoustic tomography for non-destructive testing of trees. Proceedings of 14th International Symposium on Nondestructive Testing Oof Wood, Shaker Verlag, Germany, pp. 339–349.

Nanami, N., Nakamura, N., Arima, T. and Okuma, M. 1992. Measuring the properties of standing tress with stress waves. 1. The method of measurement and the propagation path of the waves. In MokuzaiGakkaishi 38; pp. 739–746.

Pellerin, R.F. and Ross, R.J. 2002 Nondestructive Evaluation of Wood. In Forest Products Society, Madison, p. 58.

Rinn, F. 2003. Technische Grundlagen der Impuls-Tomographie. In Baumzeitung 8; pp. 29–31.

Rinn, F. 2004. Statische Hinweiseim Schall-Tomogramm von B¨aumen. In Stadt Grün 7; pp.41–45.

Tomikawa, Y.I., Arita, K. and Yamada, H. 1990. Nondestructive inspection of wooden poles using ultrasonic computed tomography. In IEEE Transactions UFFC 33(4); pp. 354–358.

Wang, J., Biernacki, J.M. and Lam, F. 2001. Nondestructive evaluation of veneer quality using acoustic wave measurements. In Wood Sci Technol 34; pp. 505–516.

Wang, X. and Allison, R.B. 2008. Decay detection in red oak trees using a combination of visual inspection, acoustic testing, and resistance microdrilling. In Arboriculture and Urban Forestry 34; pp. 1–4.

Wang, X., Wiedenbeck, J. and Liang, S. 2009. Acoustic tomography for decay detection in black cherry trees. In Wood and Fiber Science 41; pp. 127–137.

Wang, X., Divos, F., Pilon, C., Brashaw, B.K., Ross, R.J. and Pellerin, R.F. 2004a Assessment of decay in standing timber using stress wave timing nondestructive evaluation tools. In General Technical Report FPL-GTR-147. USDA Forest Service, Forest Products Laboratory; pp. 12.

Wang, X.P., Ross, R.J, Green, D.W., Brashaw, B., Englund, K. and Wolcott, M. 2004b. Stress wave sorting of red maple logs for structural quality. *In Wood Sci Technol* 37; pp. 531–537

****