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Monitoring of a Cross-Sectional Vibrational Mode in the Trunk of a Palm Tree

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Abstract. Palm trees, like all other tree species, are living entities that may be subject to the attack of several natural agents which affect the strength of the trunk. The most serious of these damaging agents are parasites and rot fungi, which proliferate in the substance of the stem, destroying its cells and fibers and weakening it. Consequently, this decay affects the physical characteristics of the modes of vibration in the tree trunk regarding resonance frequency, shape, and damping. Advanced stages of rot infection in a tree trunk may reach such an extreme level that substantial amounts of its solid mass are removed, ultimately leading to a hollow trunk rather than one of substance. In cases like these, the trunk presents less resistance to forced vibrations, and the active modes affecting the cross section of the trunk exhibit decreased resonance frequency values. This paper aims to present a method based on vibrations which might be employed for tracking a specific mode of radial vibrations known as the *ovalling* mode. To achieve this goal, the trunk of a palm tree was set into vibration via mechanical excitation in the radial direction and its response at some specific point on the trunk was examined. This method uses a single concentrated source of excitation and two vibration sensors, which are diametrically positioned and fastened to the surface of the tree trunk. The *ovalling* mode might be extracted from the frequency response by adding the signals recorded by the two sensors, which are in phase for a test specimen with a perfectly circular, cylindrical shape made of homogeneous, isotropic material. This study provides a preliminary investigation into the feasibility and reliability of this nondestructive method when applied for the identification of rot hosting by the trunks of standing trees, wooden poles, and logs, as well as the level of severity of rot attack.

Keywords. Inspection; Ovalling Mode; Palm Tree; Resonance; Rot; Trunk; Vibration.

INTRODUCTION

Palm trees are among the best-known and most widely cultivated plants in the world. Often symbolizing deserts, these trees form an essential part of the landscape, fulfilling an aesthetic role by embellishing streets or parks and shading sandy beaches. However, palm trees also serve a more important economic purpose, including date palms (*Phoenix dactylifera*) in the hot, dry Middle Eastern areas, as well as oil (*Elaeis* spp.) and coconut (*Cocos nucifera*) palm trees found in the more temperate and humid climates of the intertropical regions. Palm trees, like any other type of tree, are vulnerable to pestiferous agents, which attack the cellular and fibrous structures of the tree stem and reduce its health. Consequently, a tree with a weak trunk located in an urban space or a public park may constitute a hazard to people in its immediate vicinity. On the other hand, date and oil palm trees require periodical maintenance of their health condition, and the use of a reliable and efficient investigation technique for this purpose may be decisive before considering the felling of a diseased tree. All previous studies involving wood and trees, as well as the use of various vibrational and acoustical techniques for assessing the internal state of tree trunks, confirm that strength-weakening defects in the wood always lower the propagation speed of acoustic waves in the material. However, only a handful of studies have been devoted to investigating the vibrational modes in the stems of standing dicotyledon trees, while almost none of these have considered trees that belong to the monocotyledon families.

The degradation of palm trees by decay leads to considerable losses in terms of crop quality and quantity due to diminished growth of the affected trees. Therefore, plantation owners are forced to decide between allowing the diseased tree to occupy valuable space in the stand, or incurring the cost of felling and disposing of it. Furthermore, when considering the purchase of a palm tree stand, a buyer will require pertinent information regarding the presence of existing decaying trees, since this may affect both the price and future profitability.

Almost all tree species are vulnerable to rot attacks by certain species of fungi, which often spreads in the tree from the roots up to the trunk. Visually inspecting the tree and obtaining core samples from the trunk are two methods commonly used in forestry for the detection of decay in trees. Visual inspection is based on the subjective interpretation of external signs, often rendering this method unreliable (Wagener and Davidson 1954). The second method consists of taking core samples from the tree trunk using an increment borer and is also considered somewhat fallible in predicting the proportion of decayed trees within a tree stand. This unreliability is exacerbated when the rot is located at the pith, the center axis of the trunk, which increases the probability that the decayed area will go unnoticed when removing the core sample. Moreover, identifying decay is less likely when the core sample is extracted at breast height on the trunk instead of lower down near ground level (Stenlid and Wästerlund 1986).

Nondestructive rot detection methods based on various technologies have been suggested during the last few decades and are implemented in arboricultural pathology. Many of these methods are based on acoustical and vibrational techniques and aim at measuring the speed of wave propagation through the examined tree trunk or scanning its interior by studying its response to impulse excitation. Research involving the surface behavior of a tree trunk subjected to stress excitation is extremely limited. Therefore, these constraints could offer new investigative opportunities to determine the quality of both trees and logs before sawmill processing. Consequently, the focus has been centered on the behavior of specific low-order modes of circumferential display on tree trunks employing multi-sensor equipment and signal processing techniques (Axmon and Hansson 1999; Axmon et al. 2002; Axmon et al. 2004; Axmon et al. 2005). Regarding sonic waves, these may be in the audio or the ultrasonic frequency range and require a unique choice of sensors, which are attached with care to avoid wave scattering and minimize back reflection. On the other hand, stress waves can be generated by tapping on the test specimen with a hammer while a single sensor is used for detecting the arrival of the stress wave (Shaw 1975; Wade 1975; Bulleit and Falk 1985; Mattheck and Bethge 1993; Rust 2000; Martin and Berger 2001; Carson et al. 2006; Deflorio et al. 2008). The nature and duration of the contact between the surface of the hammerhead and the stricken object are decisive regarding the frequency content of the mechanical wave generated by the stroke. This approach uses triggers for measuring the time of induction and the time of arrival of the signal for calculating its time of flight through the mass of the tree trunk. The speed of wave propagation permits the identification of the strength of the material, which is expressed by the Modulus of Elasticity (MoE). Wood is a highly inhomogeneous and anisotropic material, and the strength properties of the material strongly depend on the direction of wave propagation within the material (Bucur 2006; Dikrallah et al. 2006; Grabianowski et al. 2006; Liang et al. 2010). The extent of the zone of affectation and the severity of attack by incipient rot in the tree trunk may be established by comparing the measured speed of wave propagation, or equivalently the MoE, depending on the degree to which the values of these parameters fall below a species-dependent threshold (Bulleit and Falk 1985; Matteck and Bethge 1993; Bucur 2013). When using either ultrasonic or stress waves, detecting the presence of rot relies on the speed of wave propagation being lower in the decayed wood than in healthy wood (Martin and Berger 2001; Rabe et al. 2004; Schwarze 2008; Wang and Allison 2008). The various travel pathways typical of the tracking signal moving across the mass of the tree trunk are processed to establish tomographic images denoting the cross section of the trunk. Picus (Argus Electronic, Rostock, Germany), Arbotom (Rinntech, Heidelberg, Germany), as well as ArborSonic 3D (Fakopp, Agfalva, Hungary) represent three pieces of equipment employed for this principle by utilizing several stress sensors and high-frequency stress waves (Divos et al. 2001; Ishaq et al. 2014; Karlinasari et al. 2015).

MATERIALS AND METHODS

The present study investigates the vibration of the trunk of a palm tree subject to excitation in the radial direction. Furthermore, a tree trunk behaves as a complex mechanical system, exhibiting various modes of vibration in response to mechanical excitation, therefore denoting vibration methods where the mechanical system changes its shape over time at specific frequencies known as Eigen frequencies, or natural frequencies. The response of the mechanical system is most pronounced for the vibration modes of the lowest natural frequencies, since these modes are not only well distinguished from each other regarding frequency, but also because they dispose of larger energy reservoirs for sustaining vibrations with larger amplitudes for longer periods (lower damping). Knowledge of the behavior, shape, and frequency of these modes may serve as a benchmark for a subsequent, more comprehensive study concerned with establishing the degree of influence of rot on the physical and geometrical attributes of these modes. Moreover, studies conducted on wood beams indicated that rot, as well as other structural defects, reduce the strength of the material as quantified by the value of its MoE. Therefore, the frequency of resonance of the flexural, or bending, modes are also diminished without significantly affecting the shape of these modes (Choi et al. 2007). Henceforth, this study focuses on a specific mode of vibration, the *ovalling* mode, in which the particles of the wood material in the trunk are moving radially with respect to the axis of the trunk. As a result, the cross-sectional shape of the trunk changes during the time of sustention of the vibration, with a typical schematic drawing of this change with respect to time shown in Figure 1 (the cross-sectional deformation is exaggerated only for demonstration purposes).

The tree specimen used in this experiment was a California fan palm (*Washingtonia filifera*) of the Arecaceae tree family, which is used as an ornamental tree along alleys, roadsides, and in picnic areas on university campuses. The measurement equipment was typical to that used for mechanical vibration experiments and consisted of a force generator for creating vibrations in the tree trunk and sensors for detecting the response of the trunk to the vibration excitation. A B&K Model Type 4810 Electrodynamic Mini-Shaker (Brüel & Kjær, Nærum, Denmark) was used to facilitate vibration excitation. This device was coupled with a steel rod called a *stinger*, which was connected to the vibrating cone of the shaker. The stinger was oriented in the radial direction of the tree trunk and attached with nuts to a small, elongated metallic plate, which in turn was fastened to the middle of the trunk with two screws, as shown in Figures 2 and 3.

The vibration sensors consisted of a pair of similar uniaxial B&K Type 4381 piezoelectric accelerometers (Brüel & Kjær, Nærum, Denmark) with a sensitivity of 10 pC/ms^{-2} and a working frequency ranging from 0.1 Hz to 4800 Hz. Considering the *ovalling* mode, Figure 1 indicates that the signals located in diametrically opposite positions on the trunk are in phase. Therefore, they simultaneously display the same vibration status, meaning that both are at maximum or at minimum amplitude when the trunk is set into radial vibration. This behavior contradicts that of bending vibrations, where diametrically opposite positions in the direction of the excitation signal vibrate out of phase. For example, when one of the

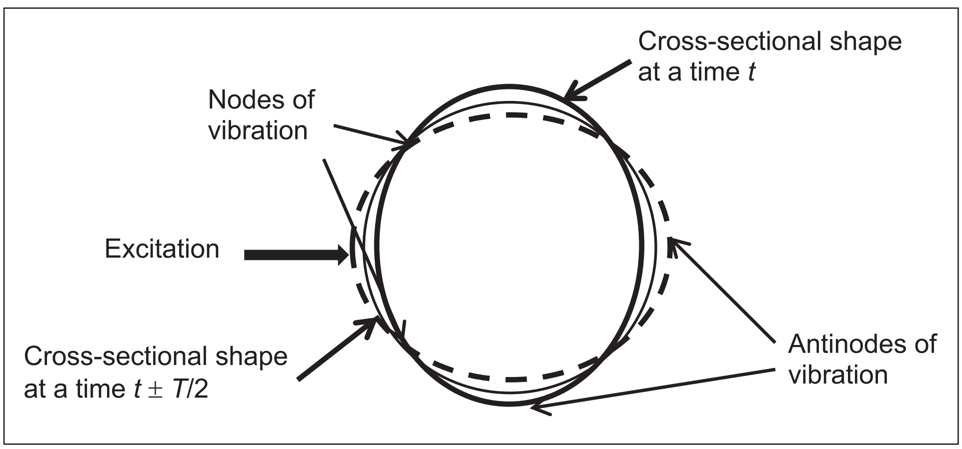

Figure 1. Illustration of the *ovalling* mode: evolution with time of the shape of the cross section of a circular cylinder as excited radially by a concentrated force. T is the period of vibration of the mode, or T = 1/fo, fo being its frequency.

Figure 2. Photograph of the experimental measurement set-up used for sensing the *ovalling* mode on a palm tree trunk.

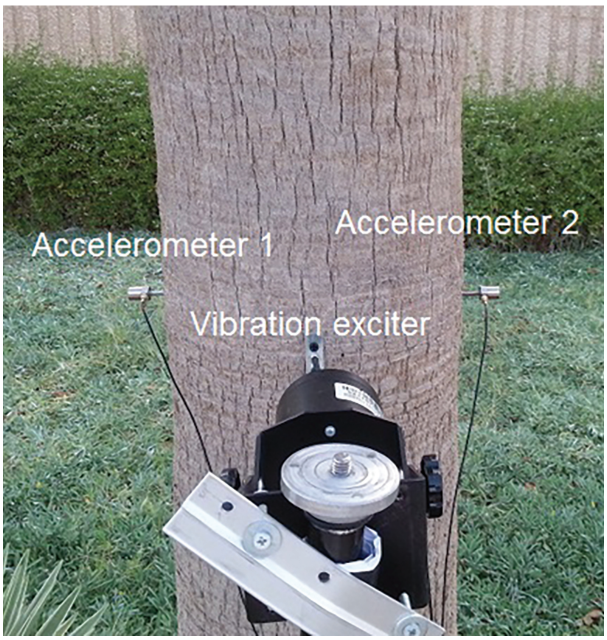

Figure 3. Close-up details of the measurement set-up in Figure 2. Attachment on the palm tree trunk of the vibration exciter and of the accelerometers for the detection of response signals.

positions is at a maximum vibration, the diametrically opposite one is at minimum vibration. The circumference of a circular cross section consisting of a thin shell of solid material would correspond to one bending wavelength in the case of the bending mode (sometimes also called *lobar* mode), whereas it would be represented by two wavelengths for the *ovalling* mode. The vibration sensors in the present experiment were also attached in lateral positions with respect to the point of action of the excitation, since these symmetrical positions allow for the vibration signal amplitudes to be of comparable amplitudes, which is not the case when one sensor is attached near the excitation point and the other one farther away. The experiments on the trunk were conducted after investigating the vibration amplitude recorded by a single sensor moved on a circumference path around the trunk. Figure 4 shows an illustration of the experimental set-up used for extracting the *ovalling* mode from the 2-sensor response of a tree trunk to a radial excitation. The amplitude of the vibration exhibited a fall-off by several dBs from the position nearest the point of application of the excitation to the point diametrically opposite on the trunk. Furthermore, in Figure 5 is shown the electronic adder, consisting of a relatively simple circuitry connecting general-purpose micropower amplifier μA741 and a few resistors, which was used for tracking the *ovalling* mode among other vibration modes through enhancing its vibration amplitude. The antinodes of the mode are signified by those positions on the circular cross section exhibiting maximum amplitude of vibration, whereas the nodes were denoted by the positions displaying the lowest amplitude of vibration (theoretically no motion).

The experimental measurements obtained in this study were used to determine the impulse response (IR), from which the transfer function (TF), that is the frequency response of the system under test, was obtained. This was achieved using a simple digital Fourier transform, which is currently incorporated in almost all digital acoustical measurement systems and runs most efficiently via the Fast Fourier Transform (FFT) algorithm. Traditionally, the IR is acquired by submitting the test specimen to a "random" noise and then executing a "cross-correlation" operation between the response signal of the system under testing (output) and the initiating signal (input). Therefore, the experimenter could control the frequency

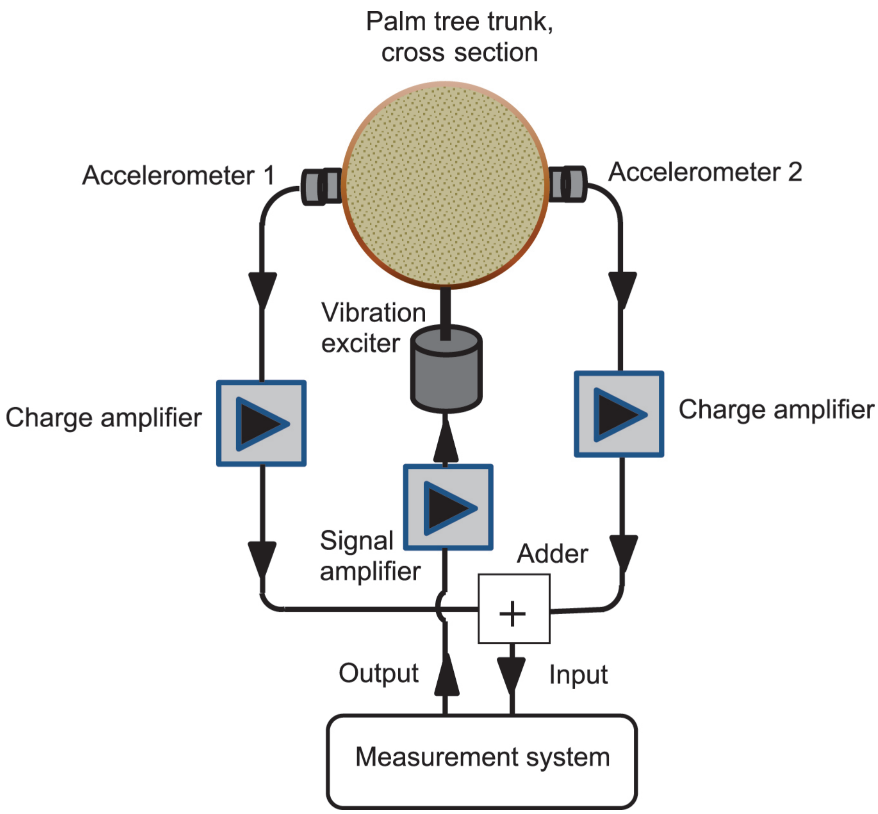

Figure 4. Schematic experimental set-up for isolating the *ovalling* mode from measurements conducted on the trunk of a palm tree set into radial vibrational excitation.

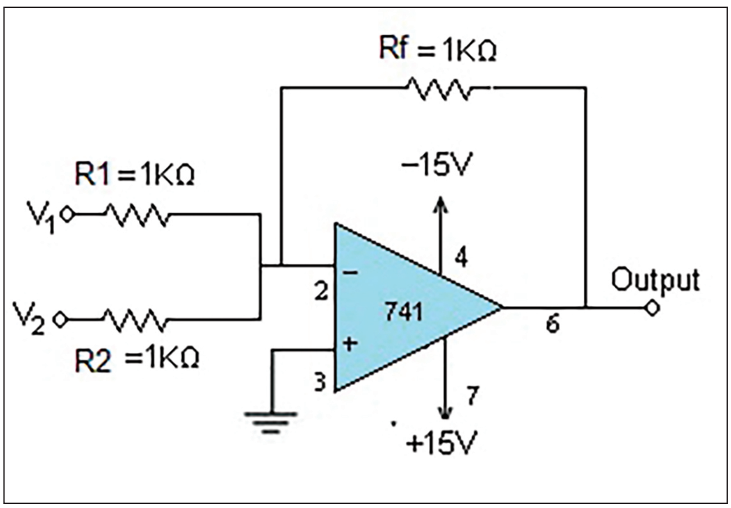

Figure 5. Electronic wiring schematics of the adder used for summing the signals from accelerometers 1 and 2 in Figure 4, consisting of simple operational amplifier µA741 and resistors of common values.

bandwidth of the excitation signal by limiting it to the range containing the resonance frequencies of all the proper modes of vibration pertinent to the study. Figure 6 provides a schematic representation of this measurement procedure, while further details are available in Kuttruff 2000.

The measurement procedure used in this study formed part of the room acoustical and simulation software ODEON®, which was initially designed for room acoustical simulations and calculations. For an appropriate level of the excitation signal above that of the background noise, and as the excitation signal is perfectly repeatable, the response result is also expected to be repeatable. The signal fed into the shaker was a chirp consisting of a sine signal sweep from 20 Hz to 20 kHz. This kind of excitation has shown superior reliability over the broad-band random noise signal excitation, since it ensures higher immunity against distortion (Müller and Massarani 2001).

One end of a threaded headless bolt 1.5 in (3.8 cm) in length was secured to the base plate of each of the measurement vibration sensors, while the other end was sharpened to facilitate attachment to the trunk mass. Furthermore, each of these accelerometers had an axis of least sensitivity to ensure that when they are oriented in a direction where the axis was parallel to that of the excitation force, it leads to minimum interference of the bending modes with the *ovalling* mode in the recorded signal. Following attachment of the accelerometers to the trunk in diametrically opposed positions, the signal received from each of them was then conveyed to a charge amplifier model B&K 2626 (Brüel & Kjær, Nærum, Denmark) with the appropriate sensitivity calibration and signal amplification. The same settings were maintained on both charge amplifiers, and the amplified signals were subsequently directed to the inputs of the adder providing the signal-sum to be fed into the system for data processing and analysis.

RESULTS

Graphs presenting the time history of the signal and its Fourier transform, i.e., the transfer function or frequency spectrum, are shown in Figure 7 and Figure 8, respectively. The *ovalling* mode exhibited its presence in the clear peak at 1340 Hz in the graph of the amplitude of the frequency response as plotted in Figure 9.

DISCUSSION

Other extensional modes of higher order were also expected to be excited in the palm tree trunk, such as $n = 3$ and $n = 4$, n being the number of circumferential wavelengths, representing an analogy for a cylindrical shell of circular cross section and the equivalent number of bending wavelengths along the circumference, as shown in Figure 10. For $n = 3$, the mode was antisymmetric, and the additional signals recorded by the opposite sensors would result in a cancellation, whereas for the $n = 4$ symmetric mode, these signals were in phase and their addition would result in amplification. The frequency of the latter mode would be that of the peak in the curve at around 2805 Hz.

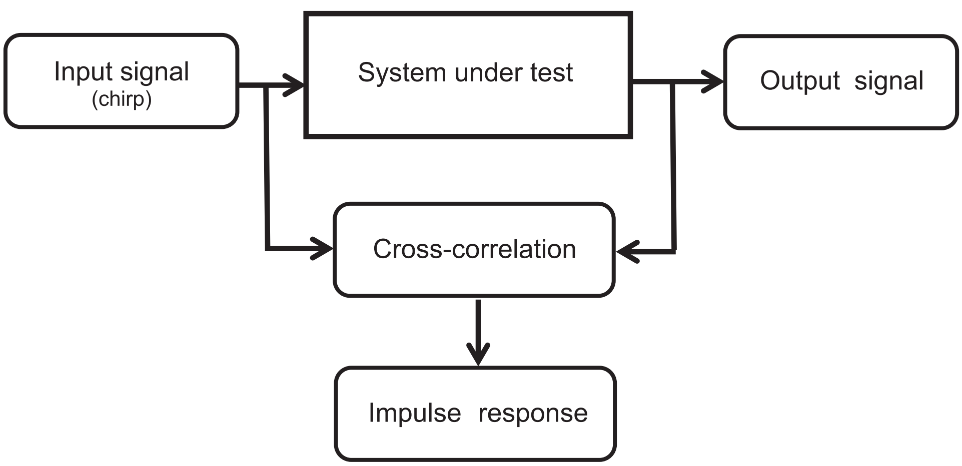

Figure 6. Illustration of the general principle behind the measurement procedure used for acquiring the impulse response of a system.

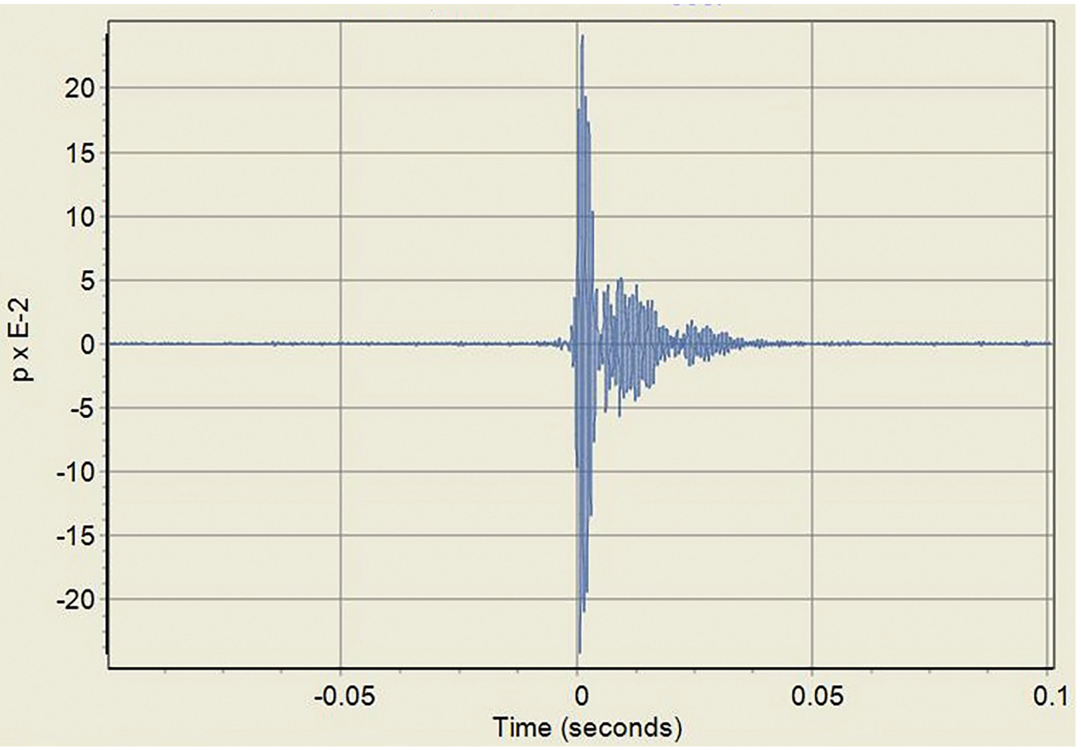

Figure 7. Impulse response as the sum of signals recorded by accelerometers 1 and 2 in Figure 3. Y-axis: acceleration, arbitrary units. Height of shaker and accelerometers: 145 cm. Circumference of trunk at measurement position: 93 cm.

Figure 8. Amplitude of the transfer function, i.e., the transform of the impulse response in Figure 7, in the frequency domain. In blue: actual untreated curve. In red: smoothed curve.

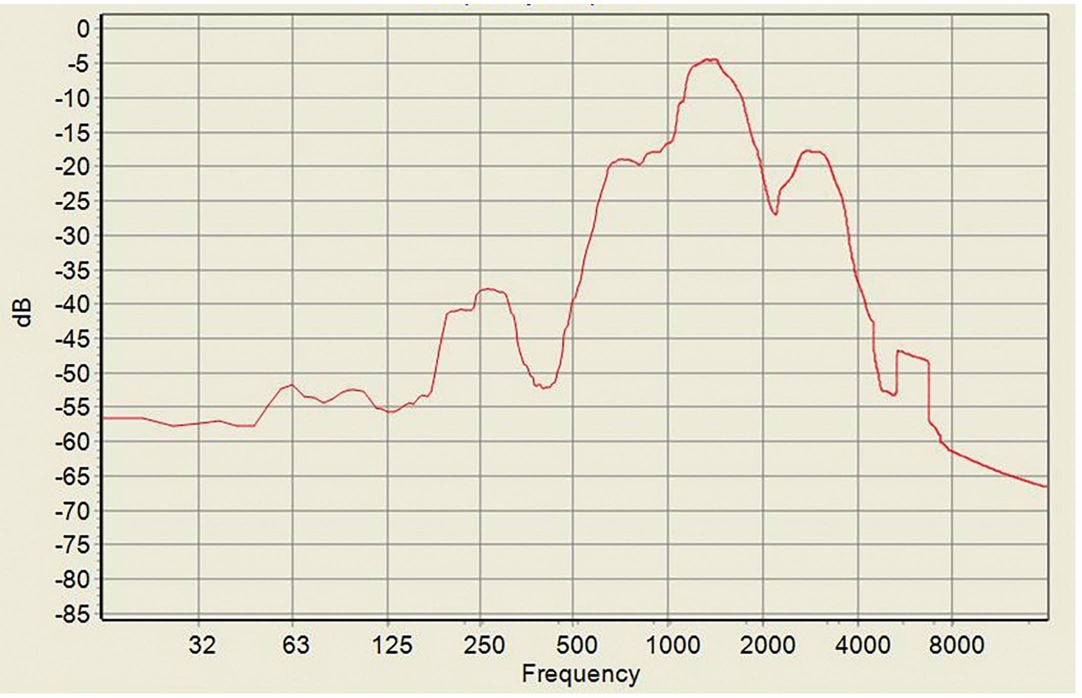

Figure 9. Amplitude of the transfer function, i.e., the transform of the impulse response in the frequency domain, smoothed curve.

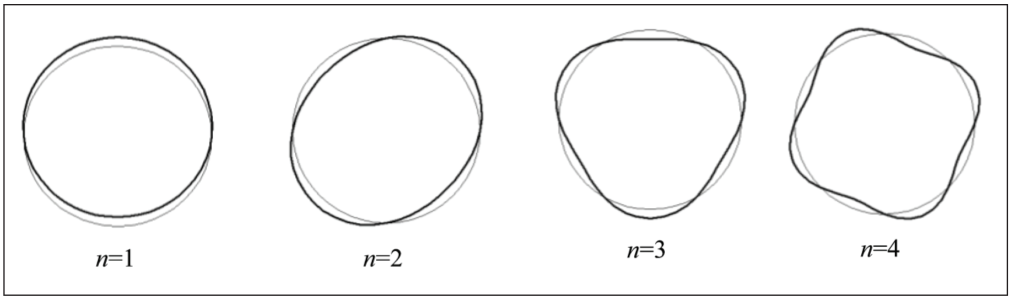

Figure 10. Shape of the various circumferential modes of lowest order for a cylindrical shell with circular cross section in radial vibration. For a thin shell, *n* corresponds approximately to the number of bending wavelengths. *n* odd: antisymmetric modes; *n* even: symmetric modes.

The odd behavior of the frequency curve at frequencies above 4 kHz could be attributed to the rapid decline in the sensitivity of the vibration sensors, and the frequency band, which is limited at about 5 kHz.

The *ovalling* mode was investigated at three different heights on the palm tree trunk above the ground. Its frequency was found to be lower when the circumference of the trunk was more extensive at the location where the measurement was taken, i.e., closer to the ground. Lastly, it was found that the action of the *ovalling* mode was localized to some extent, meaning that its amplitude of vibration exhibited a significant lateral decrease away from the plane of application of the excitation force. Therefore, examination indicated that at a lateral distance of around 15 cm from the attachment plane of the shaker, the signal recorded by the accelerometers was so weak that it was masked by background noise to such a degree that the peaks of the extensional modes in the curve of the frequency response were no longer discernible.

The frequency f_2 of the *ovalling* mode for an infinitely long circular isotropic homogeneous cylinder is related to the radius a of the cylinder and the speed c of wave propagation in the cylinder as (McMahon 1964):

$$\frac{2\pi f_2 a}{c} = 1.46 \quad (1)$$

for a material with a Poisson ratio $\nu = 0.293$ (the value 1.46 in Equation 1 is to be replaced by 1.433 for $\nu = 0.344$). Wood is a highly anisotropic material and has a Poisson ratio that depends on the direction of application of the stress (Sliker 1972; Kumpenza et al. 2018). However, using Equation 1 for the frequency of 1340 Hz in Figure 9 at a position on the trunk where the circumference, $2\pi a$, is 0.93 m resulted in a value of 854 m/s for the speed of wave propagation c. By using this value in the expression, with the MoE E for the speed of longitudinal waves:

$$c = \sqrt{\frac{E}{\rho}} \quad (2)$$

and by setting a rough value of $\rho = 600$ kg/m^3 for the density of the trunk material, an approximate value of 0.44 GPa was obtained for the MoE, which is within the range of values as given by Rich 1987 for palm tree wood. Moreover, due to the material anisotropy, the speed of wave propagating across the grain of the fibers might be different from the value obtained when wave propagation is in the longitudinal direction, i.e., along the fibers.

Table 1 summarizes the results from calculating the resonance frequency values as measured at three different heights on the trunk of the same palm tree. Although the tree trunk maintained an approximate constant cross-sectional size above a certain height (above ca. 2.50 m relying on visual assessment), the flaring was noticeably more pronounced below a height of 0.80 m. Table 1 indicates that the value of the resonance frequency increased at the higher measurement positions, such as a decrease in the size of the trunk circumference. This result was logical from a physical point of view, since vibrating systems of smaller sizes display higher frequencies of resonance, which is also in accordance with Equation 1. However, a more careful analysis of the data reveals that the dependence of the wave propagation speed was not limited to a simple inverse proportionality to the circumference of the trunk. Therefore, a change in the value of the wave speed, and consequently of the MoE, was also observed as a function of height (at least for measurements made at the low heights above the ground in the present experimentation). An authentic relationship is necessary for increasing the resonance frequency, not only regarding the circumference (i.e., height), but also regarding the speed by which the wave propagation decreased. This observation confirms the earlier findings involving the mechanical properties of palm trees, a fact that is probably valid for all trees, that the trunk distinctly exhibits higher strength characteristics at its base and at the rim of the trunk, allowing the tree to withstand excessive bending resulting from the action of strong winds (Rich 1987; Gibson 2012). Therefore, further research is necessary to explore whether the increased strength results from the tree developing thicker and stronger fibers at these particular positions on the trunk, or whether this is due to some other process where stronger fibers are generated for reinforcing the existing weaker ones.

CONCLUSIONS

In conclusion, this paper examined isolating a cross-sectional mode from the frequency response of the trunk of a palm tree set into vibration. The method used builds on the attachment of two vibration

Table 1. Summary of results from measurements conducted on the same palm tree at different heights on the tree trunk.

Height (m) above ground	Circumference $2\pi a$ (m)z	Resonance frequency f_2 (Hz)	c (m/s)[1]	MoE (GPa)[2]
0.46	1.19	1155	942	0.533
0.80	1.06	1230	893	0.478
1.45	0.93	1340	854	0.438

[1] Equation 1. [2] Equation 2.

sensors in diametrically opposed positions on the surface of the tree trunk to detect the response to radial excitation. The positions of the vibration sensors and the point of application of the excitation signal are on the same plane, normal to the axis of the trunk, with the excitation point midway between the sensors. This study focuses on a specific extensional mode of vibration, namely the symmetrical *ovalling* mode, which is ranked number two in the series of radial modes for vibrating solid or hollow cylinders of circular cross-sectional shape. This mode is isolated in the frequency response of the tree trunk by adding the in-phase signals recorded by the two vibration sensors. The resonance frequency value of this mode permits the identification of the wave propagation speed in the trunk, and, therefore, the value of the MoE in the transverse direction of the trunk. For a cylinder of homogeneous isotropic material, the speed of wave propagation is inversely proportional to the circumference of the trunk, while the MoE value is equal to the product of the values of the material density and the square of the wave speed. Wood being a distinctly anisotropic material, the speed requiring consideration in this context is the transverse speed of waves propagating across the trunk, which may be different from the speed in the longitudinal direction, i.e., along the grain. In this study, a high-quality vibration exciter and particular measurement software were used to obtain the response of the tested object. However, field measurements require a different type of test instrumentation. Therefore, a hammer is used for generating the stress signal and for acquiring a direct signal approaching the ideal impulse response. In this respect, special attention is also to be paid to the contact surfaces between the hammer and the exterior of the trunk, as well as a consideration to the calibration procedure in which the hammer stroke is adjusted to the specific tree species (from very soft to very hard) and the transverse size of the tree trunk. Furthermore, this investigation found that the value of the MoE increases at the base of the tree trunk, but the degree to which this value changes in conjunction with the height of the trunk requires further investigation. A similar study to the present one is in progress involving the trunk of a monocotyledon tree displaying circular concentric tree rings and for which the transverse anisotropy of material constituting the wood of the trunk exhibits both radial and tangential components.

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Résumé. Les palmiers, comme toutes les autres espèces d'arbres, sont des entités vivantes sujettes aux attaques de plusieurs agents biotiques qui affectent la résistance du tronc. Les agents déprédateurs les plus sérieux sont les parasites et les champignons de pourriture, qui prolifèrent à l'intérieur du tronc, détruisant ses cellules, ses fibres et affaiblissant ce dernier. En conséquence, cette pourriture modifie les caractéristiques physiques des modes de vibration dans le tronc concernant la fréquence de résonance, la forme et l'amortissement. Les phases avancées d'infection par la pourriture du tronc peuvent atteindre un tel niveau extrême où des quantités substantielles de matière solide seront disparues, menant finalement à un tronc creux en lieu et place de matière. Dans de tels cas, le tronc montre une résistance moindre aux vibrations forcées et les modes actifs affectant la section transversale du tronc présentent des valeurs de fréquence de résonance réduites. Ce document vise à présenter une méthode basée sur les vibrations pouvant être utilisée pour retracer un mode spécifique de vibrations radiales connu sous le nom de mode d'*ovalisation*. Pour atteindre cet objectif, le tronc d'un palmier a été mis sous vibration via une excitation mécanique dans le sens radial et sa réponse en divers endroits du tronc fut analysée. Cette méthode utilise une seule source concentrée d'excitation et deux capteurs de vibration, lesquels sont positionnés et fixés diamétralement à la surface du tronc. Le mode d'*ovalisation* peut être extrait de la réponse en fréquence par l'ajout des signaux enregistrés par les deux capteurs, qui sont en phase pour un échantillon d'essai de forme cylindrique parfaitement circulaire en matériau homogène et isotrope. Cette étude fournit une investigation préliminaire sur la faisabilité et la fiabilité de cette méthode non-destructrice lorsqu'utilisée pour l'identification de la pourriture du tronc d'arbres sur pied, de poteaux de bois ou de billots, ainsi que le niveau de gravité des attaques de pourriture.

Zusammenfassung. Wie alle anderen Baumarten sind Palmen Lebewesen, die dem Angriff mehrerer natürlicher Agenzien ausgesetzt sein können, die die Festigkeit des Stammes beeinträchtigen. Die schwerwiegendsten dieser schädlichen Agenzien sind Parasiten und Fäulnispilze, die sich in der Substanz des Stammes vermehren, seine Zellen und Fasern zerstören und ihn schwächen. Folglich beeinflusst dieser Zerfall die physikalischen Eigenschaften der Schwingungsmoden im Baumstamm hinsichtlich Resonanzfrequenz, Form und Dämpfung. Fortgeschrittene Stadien der Fäulnisinfektion in einem Baumstamm können ein so extremes Niveau erreichen, dass erhebliche Mengen seiner festen Masse entfernt werden, was letztlich zu einem hohlen Stamm führt. In solchen Fällen weist der Stamm einen geringeren Widerstand gegen erzwungene Schwingungen auf, und die aktiven Modi, die den Querschnitt des Stammes beeinflussen, weisen verringerte Resonanzfrequenz-Werte auf. In diesem Beitrag soll eine auf Schwingungen basierende Methode vorgestellt werden, die zur Verfolgung eines bestimmten Modus radialer Schwingungen eingesetzt werden könnte, des so genannten Ovalling-Modus. Um dieses Ziel zu erreichen, wurde der Stamm einer Palme durch mechanische Bewegung in radialer Richtung in Schwingung versetzt und seine Reaktion an bestimmten Punkt des Stammes untersucht. Diese Methode verwendet eine konzentrierte Anregungsquelle und zwei Schwingungssensoren, die diametral positioniert und an der Oberfläche des Baumstammes befestigt sind. Der Ovalling-Modus kann aus dem Frequenzgang extrahiert werden, indem die von den beiden Sensoren aufgezeichneten Signale addiert werden, diese sollten bei einem Prüfkörper mit perfekt kreisförmiger, zylindrischer Form, die aus homogenem, isotropem Material besteht, in Phase sein. Diese Studie liefert eine vorläufige Analyse der Durchführbarkeit und Zuverlässigkeit dieser zerstörungsfreien Methode bei der Anwendung zur Identifizierung der Fäulnis, die in den Stämmen von stehenden Bäumen, Holzpfählen und Baumstämmen auftritt, sowie der Ausdehnung der Fäulnis.

Resumen. Las palmeras, como todas las demás especies de árboles, son entidades vivientes que pueden estar sujetas al ataque de varios agentes naturales que afectan a la resistencia del tronco. Los agentes más graves son los parásitos y los hongos de pudrición, que proliferan en la sustancia del tallo, destruyendo sus células y fibras debilitándolo. En consecuencia, esta descomposición afecta a las características físicas de los modos de vibración en el tronco del árbol con respecto a la frecuencia de resonancia, la forma y la amortiguación. Las etapas avanzadas de la infección por podredumbre en un tronco del árbol pueden alcanzar un nivel tan extremo que se eliminan cantidades sustanciales de su masa sólida, lo que en última instancia conduce a un tronco hueco en lugar de uno de sustancia. En casos como estos, el tronco presenta menos resistencia a las vibraciones forzadas y los modos activos que afectan a la sección transversal del tronco presentan valores de frecuencia de resonancia disminuidos. Este documento tiene como objetivo presentar un método basado en vibraciones que podrían emplearse para rastrear un modo específico de vibraciones radiales conocido como el modo *ovalado*. Para lograr este objetivo, el tronco de una palmera se puso en vibración a través de la excitación mecánica en la dirección radial y se examinó su respuesta en algún punto específico del tronco. Este método utiliza una única fuente concentrada de excitación y dos sensores de vibración, que se colocan diametralmente y se fijan a la superficie del tronco del árbol. El modo *ovalado* podría extraerse de la respuesta de frecuencia añadiendo las señales registradas por los dos sensores, los cuales están en fase para una muestra de ensayo con una forma perfectamente circular y cilíndrica hecha de material isotrópico homogéneo. Este estudio proporciona una investigación preliminar sobre la viabilidad y fiabilidad de este método no destructivo cuando se aplica para la identificación de la podredumbre que se aloja en los troncos de árboles en pie, postes de madera y troncos, así como el nivel de gravedad del ataque de la podredumbre.