Ultrasonic device for the imaging of green wood

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Abstract

Wood is a biological and natural growth-medium. This medium is orthotropic and its production varies in response to environmental conditions, and obviously, according to tree age. As such, variations in material properties are much more complex than anisotropy. For standing trees, numbers of auscultation tools are available and marketed. The objective of the BioGMID project is to create an efficient and optimized procedure for characterization and cross-sectional imaging of standing trees based on ultrasonic and X-ray imaging. An ultrasound measurement suitably combined with an X-ray measurement should allow a qualitative and quantitative high-resolution analysis of the structure. This article reports the development of a specific ultrasonic imaging device which can be used in tropical forest plantations. Fast characterization of plantation trees could be a useful tool for clonal selection and genetic improvement.

Introduction

Non-destructive techniques based on X-rays or acoustic waves were developed and adapted to wood material from the 1960s [2]. The main acoustical tomographic devices such as “Picus Sonic” [6, 7] and “Fakhopp 2D” [3] and Arbotom [4, 5], are based on speed-of-sound measurement throughout the cross-section. A limitation of these tools is that only the transmitted waves are exploited and the dominant parameter measured is only the velocity of the longitudinal waves, which is an important parameter, but not sufficiently sensitive to identify different layers and properties. An improved measure would be based on both diffraction and transmission measurements of ultrasounds. The use of diffraction allows qualitative imaging like *echography*. The transmission wave analysis allows the local assessment of specific modulus and internal damping (quantitative imaging).

The research project BioGMID (Biological Growth Medium Integrity Diagnoses using bi-modality tomographies) relates to the development of a methodological tool based on X-ray and ultrasound computed tomographies. Firstly, a qualitative approach may be applied to characterize the integrity of multi-scaled materials, and secondly, a quantitative approach may be applied to assess physical properties (density, atomic effective number, elastic stiffness constants). This project provides an enhanced knowledge of wave/medium interaction phenomena. This article is focused on the ultrasonic aspect of the project, particularly the development of a specific ultrasonic device for the imaging of standing trees.

Methodology of conception

Our objective is to develop a specific ultrasonic imaging device which can be used in tropical forest plantations. We believe that non-destructive characterization of plantation trees, in terms of mechanical behavior and also in early detection of internal deterioration, could be a useful tool for clonal selection and genetic improvement.

The main requirements for the tomographic device were:

- Weight between 10 and 20kg.
- Assembly done in few minutes.
- Use of battery power supply.
- Trunk diameter between 15 and 50 cm.
- Two ultrasonic sensors should be moved around the tree separately.
- Optimal scanning time was between five and 10 minutes (depending on the image resolution).

The conception and production of the device were made at CIRAD during one year. The production process is not yet achieved. The mechanical parts were designed using computer-aided design software, so that a virtual device was first built to verify its functionalities compared with the requirements. The electronic parts were also designed at CIRAD including the square impulse generator, the analogic to digital converter, the specific data storage and the control card with its specific driver for the automatic scanning process.

Results

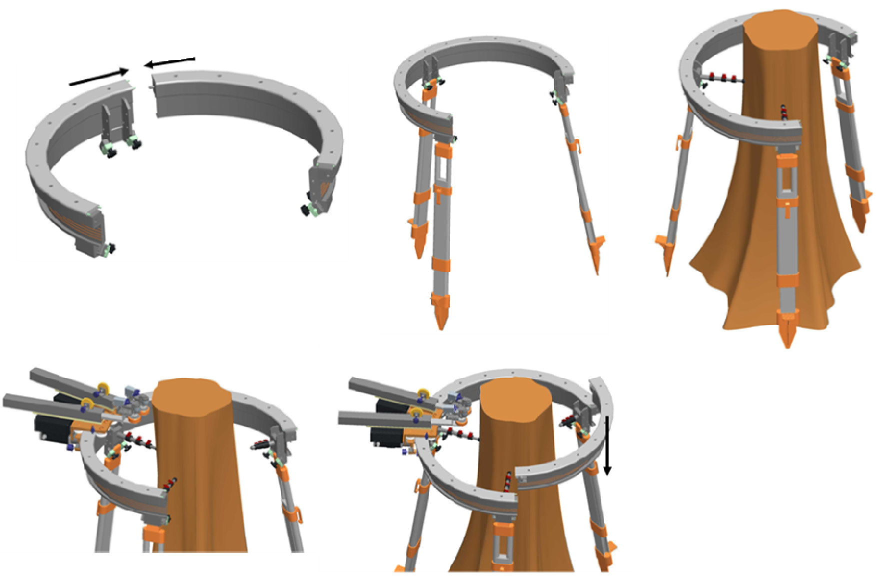

Fig. 1 Schematic view of the device assembly.

The device is consists of an aluminum ring supported by a tripod (*Fig 1*). The height of the ring can be adjusted from 1 m to 1.6 m but the typical height is 1.3 m. The two parts of the ring are first assembled, and then the tripod is fixed. The apparatus is then placed against the trunk using two narrowing elements. Each probe is mounted on a trolley and these trolleys are slipped within the ring. Finally, the last part of the ring is fixed and the third narrowing element is applied.

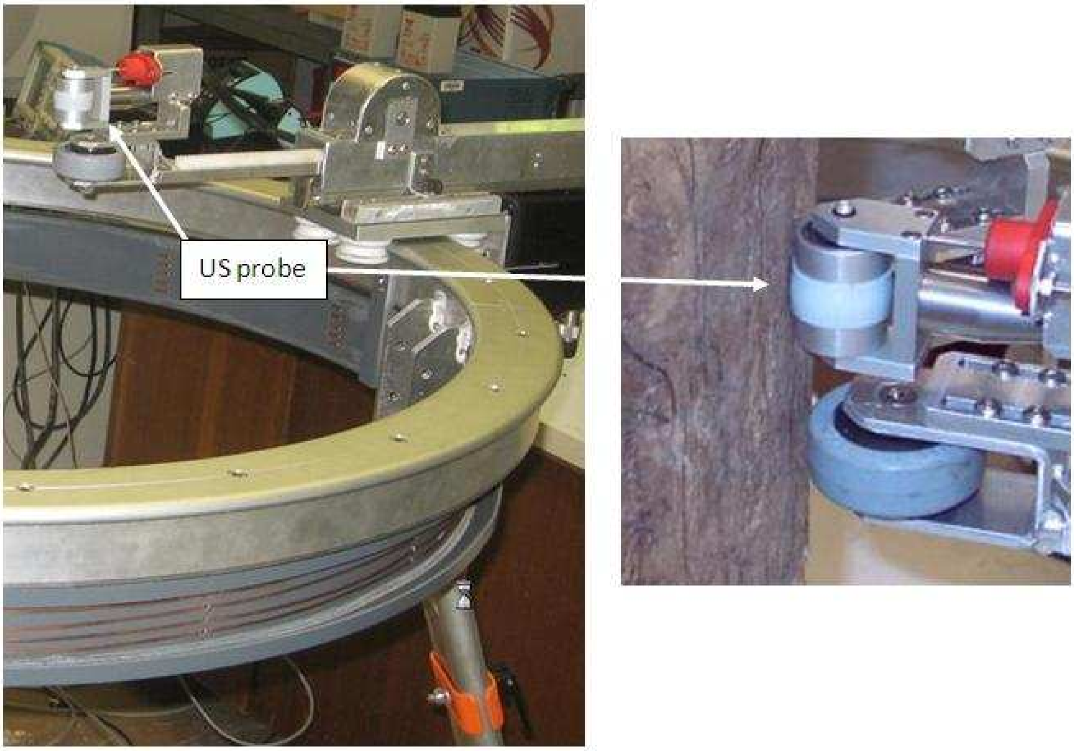

Fig. 2 Development of the ultrasonic device in CIRAD laboratory.

The ultrasonic probes have a frequency bandwidth centered on 300kHz. The associated wavelength is around 5 mm in the case of transverse scanning. The probe consists of a wheel in which the emitter is placed. The coupling medium is made by an elastomer surrounding the wheel (*Fig 2*). The emission is a square impulse of a 500V magnitude. The acquisition is performed by a converter of 16 bits resolution and a sampling frequency of 5 MHz. The duration of acquisition is set to 1800 µs (667 µs is the theoretical duration for a diameter of 50 cm).

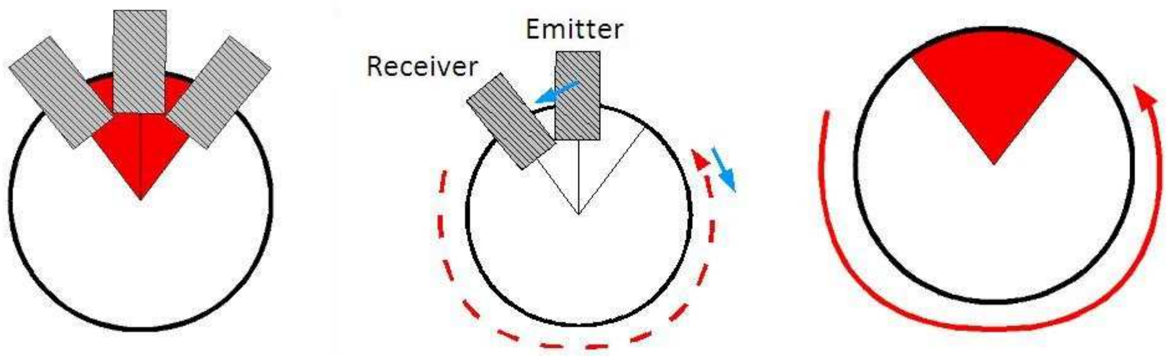

Fig. 3 Principle of the scanning process for quantitative imaging.

The tomographic image can be obtained in quantitative analysis (two probes) or in echographic analysis (one probe). The echographic analysis technique was previously discussed [1]. Concerning quantitative imaging, the scanning process is shown in the *Fig 3*. Because of the dimension of each trolley, an angular sector of 120° cannot be scanned in one projection (red sector, *Fig 3*). A typical angular step of 5° leads to a number of acquisition of about 48 for 1 projection. For a complete scan, the total number of acquisition is thus 3456. For a projection, the emitter is motionless while the receiver moves around the ring. The next projection is initiated by a 1 angular step motion of the emitter followed by another motion of the receiver all around the ring (an acquisition is done at each angular step).

Perspectives

The ultrasonic tomographic device will be fully functional in October 2009. At this time, laboratory tests will start first on an "academic" object to determine the real bias in the image computation. Subsequently, green logs will be assessed. These logs are already stored in a water tank at CIRAD and were selected based on the irregularity of their bark. The irregularity of the bark induces a problem of coupling between the probe's elastomer strip and the wood. It is indeed planned to test the logs with and without the bark; and a new design of the probe shape could also be considered.

Partnerships

The partners of the wood aspect of the BioGMID project have significant experience of imaging and tomography of biological media.

LMA (Laboratoire de Mécanique et d'Acoustique), the French leader on ultrasonic tomography, has developed experimental and theoretical/numerical solutions, and signal processing tools, for non-destructive evaluation and control of biological, natural or manufactured materials.

CNDRI (INSA Lyon, Laboratory of Controle Non Destructif par Rayonnements Ionisants) is specialist in non-destructive testing using ionising radiation and has developed efficient experimental devices of X-ray tomography, and has developed image analysis and simulation tools.

CIRAD (Centre de coopération internationale en recherche agronomique pour le développement, Production and Processing of Tropical Woods unit) is the French agricultural research centre working for international development in tropical areas, involved in developing the use of wood, for construction, housing and civil engineering purposes, and has developed acoustic vibration analysis devices to evaluate timber properties and their variability (http://www.xylo-metry.org/).

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