

# Ultrasonic imaging of wood structure

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## Abstract

*The purpose of this report was firstly to obtain an ultrasonic image with a thin (2 mm thickness) solid wood specimens, without a special preparation of the surface, which are used currently for X - rays microdensitometric technique, and secondly, to obtain an ultrasonic image of a very thin microscopic section (12µm), fixed between two glass lamellae. This specimen is the classic specimen used for optical microscopic studies of wood anatomic structure. The images were obtained with the scanning acoustic microscope, SONOSCAN - C - SAM D 9000, in a frequency range between 100 MHz and 230 MHz , for two species : spruce and oak. The image resolution was between 10µm and 25 µm. It was observed that it possible to establish a relationship between the amplitude of the ultrasonic signal and the corresponding microdensitometric value of different anatomical elements.*

*Keywords : scanning acoustic microscopy , wood imaging , X-ray microdensitometry*

## 1 Introduction

Scanning acoustic microscopes allow the imaging of wood structure through the ultrasonic reflectivity of the sample, measured point by point and displayed on a screen. As for optical microscope, for acoustical one the resolution is obtained by focussing radiation to a diffraction limited spot. Nevertheless, the main interest of developing acoustic microscopic ultrasonic technique is determined by the fact that subsurface images can be obtain, because the ultrasonic waves can penetrate the opaque wood surface.

Today the use of acoustic microscopy technique is well established. The field of application of this technique as an advanced nondestructive testing is very wide. Studies of wood structure are relatively scarce today. Imaging of wood structure of oak, spruce and pine was obtained in the reflection mode using lens focused at 200 MHz. [1]. The image resolution was of 6 µm in a scanning dimension ranging between 50µm and 5 mm.

Details of oak round ring porous growth pattern, zones of fibers and multiseriate rays were clearly seen in all three anisotropic planes. The anatomical details observed in spruce and pine are : the latewood, the earlywood , the medulary rays and the pits. Very clearly the diameter of the pit can be seen. More recently, images of the gelatinous layer of tension wood were obtained at 600 MHz frequency, with a resolution of 2µm.. The characterization of the interfaces between different layers of the cell wall, and between the wall and the amorphous layer

containing a big amount of lignin, is an enormous progress in the advancement of wood science.

At frequencies higher the 1 GHz the wavelength in water is of 0.8 µm, which means that this submicrometer resolution is approaching that of an optical microscope. In this case, a dominant role in image contrast is played by the Rayleigh waves, which are excited at the surface of the sample. The ultrasonic signal depends on the value of the surface wave velocity in the sample. An other interesting point is the fact that this wave contains longitudinal and shear components, each of which decays exponentially with depth. The sensitivity to the discontinuities of the structure can become much more higher, because of the differences between the anisotropic elastic properties of fibers that can have different orientations and consequently can be seen with different contrast.

## 2. The aim of the study

The aim of this study has been to explore the capability of the ultrasonic microscope SONOSCAN - C - SAM D 9000, in reflection mode, to produce images of wood structure at microscopic level in both softwood and hardwood species.

Following anatomic elements were analyzed :

- annual ring width, proportion of earlywood and latewood in annual ring,

- characteristic anatomical elements such as : tracheids, vessels and fibers, uniseriate and multiseriate medullary, parenchyma cells .

It is interesting to compare the ultrasonic data of these images with the X- ray microdensitometric data of the same specimen, namely to relate the ultrasonic signal (amplitude) with X-ray microdensitometric values.

### 3. Material and Method

#### 3.1 Specimens

Specimens of two species were selected : oak and spruce. The specimens are barrettes of 2 mm thickness, cut with the length in radial direction of the tree.

The specimens were presented to the ultrasonic scanning in the same way as for radiographic inspection. The ultrasonic energy travel in longitudinal direction and the image obtained is the ultrasonic image of wood structure obtained by scanning in the transversal anisotropic plane, showing several annual rings with different width and with different proportion of earlywood and latewood zones. Each zone from the ultrasonic image can be related with the corresponding zone of the X-ray microdensitometric graph.

To facilitate the comparison between the images obtained on barrettes of 2 mm thickness and on microscopic sections, of 12  $\mu\text{m}$  thickness both specimens were cut from the same block. The microscopic section was then mounted between two glass lamellae and fixed with a natural resin (Canadian balsam). The thickness of the upper glass lamella that cover wood section was of 0.2 mm thickness.

#### 3.2 Acoustic microscope

The ultrasonic images were obtained with scanning acoustic microscope SONOSCAN C- SAM D-9000, which allows the measurement of acoustic impedance of samples. The larger the echo and the greater the image contrast is obtained when, larger impedance difference across the interface can be measured. Digital image analyzer used 30 algorithms to quantify the interface data. The image is comprised of thousand or millions pixels, depending upon the size of the scan area and the pixel density. In our case, by scanning immersed wood specimens in water, 1024 x 960 pixels were used for an images of 20x16 mm. Each pixel corresponds to an echo from a XY position on the sample. The echoes from each scan position are displayed as brightness gray scale

(on which the echo size can be seen), or as color scale (on which the echo polarity can be seen) .

The piezoelectric transducers used were of 100 MHz and 230 MHz, operating in reflection mode. The image resolution was between 15 $\mu\text{m}$  and 25 $\mu\text{m}$ , depending of transducers frequency. A digital waveform display the ultrasonic echoes arrived from different anatomical elements of wood. Relative amplitude of each echo can be quantified. The scan size can vary between 1.3x1.3 mm<sup>2</sup> and 76x76 mm<sup>2</sup>.

For imaging 256 level gray scale is available as well as 32 color enhancement maps.

The spatial resolution is dependent on the characteristics of the material tested, transducer frequency and working distance .

### 4. Results

As regards the structure of oak, the following anatomical characteristics are observed in the annual ring:

- two main zones, the earlywood with large round vessels of 100-500  $\mu\text{m}$  diameter, representing about 20 % from the total annual ring width, and the latewood zone composed from small vessel of 24-70  $\mu\text{m}$  diameter,
- typical pattern of fibers and parenchymial cells ,
- in a position perpendicular to the vessel raw , the medullary rays of about 500-1000 $\mu\text{m}$ , wide,

The structure of spruce is much more simple, with a wide zone of earlywood and a very narrow zone of latewood. In latewood the tracheids are very small in diameter < 20  $\mu\text{m}$ . In earlywood the tracheids are larger of about 40 $\mu\text{m}$  diameter. The medullary rays are very narrow, composed from one cellular raw.

The imaging of spruce structure with 100 MHz frequency has shown in each ring the zone of earlywood (dark) is well differentiated from the zone of latewood (clear). The corresponding X-ray microdensitometric profile was studied. To each point from the ultrasonic image a corresponding value of density can be attached and the position of each ring can be co-located on acoustic image and on microdensitometric profile.

Acoustic imaging seems to be much more sensitive to the presence of the compression wood than X-ray densitometric technique.

### 6. References

- [1] V. Bucur, "Acoustics of wood". CRC Publ. Inc, Boca Raton, USA, 1995