Relationships between quantitative anatomy, microstructure, and vibrational properties of wavy maple wood

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Ahmad Alkadri[1,2], Capucine Carlier[2], Patrick Langbour[3], Iris Brémaud[2]

[1] Double Degree Master student of AgroParisTech, France, and Bogor Agricultural University, Indonesia
[2] Wood Team, LMGC (Laboratoire de Mécanique et Génie Civil), CNRS, Université de Montpellier, France
[3] BIOWooEB Research Unit, CIRAD, Montpellier, France

Abstract

Wavy sycamore maple wood is highly prized in the market for its utilization as manufacturing material for violin. However, studies on its peculiar wave-like properties are still limited. Thus, the aims of this research are to determine the anatomical, microstructural, and wave-like figures characteristics and their correlation with each other, in link with vibrational properties.

1. Introduction

Sycamore maple is capable of possessing a particular type of figure known as wavy wood [1]. This unusual characteristic is scarcely found in the natural settings and, even in the rare trees that will exhibit this prized figure, it requires seven to ten years to manifest itself [2]. Coupled with its high value among the musical instrument makers [3], there is a great interest in deepening the knowledge of its properties. Most past studies took into account some of sycamore maple's physical, mechanical, and acoustical characteristics which influences strongly on the quality of manufactured instrument [4], [5]. However, these studies were often based on a reduced panel of wood variability, and, currently, studies on its anatomical properties, and their relationships with other characteristics of the wood, are still limited. Thus, this research was conducted with the aim to quantify the anatomical properties of the wood and its wave-like figure; moreover, the relationships between said anatomical properties with microstructure and vibrational characteristics are also discussed.

2. Material and Methods

Two types of maple (wavy and non-wavy) wood were used for measuring the vibrational properties. The experiments were conducted using Vybris testing device according to the methods described by Brémaud *et al*. [6]. For anatomical and waviness measurement, 12 wood specimens with varying wave-like figures were used in this research; all specimens were actual blank plates sold for violin back plates, under different "quality grades". 11 of them are *Acer pseudoplatanus* L. and 1 of them is *Acer campestre* L. From each specimens, two 2 cm × 2 cm × 2 cm cubes were cut, one for microfibril angle (MFA) measurement and one for rays measurement. Small blocks with different sizes (width 2—3 cm, length 3—4 cm, height 3—4 cm) were also cut for the measurement of their wave-like figures. For MFA measurement, microtome slices were made based on the light microscopy MFA methods [7]. For rays measurement, slices with 15 μm thickness were made using rotary microtome and measured using light microscopy. Using ImageJ, the measurements of wave-like figures were conducted with the scanned images of the wood blocks that had been split parallel to its grain. From the figures, amplitude (A) and wavelength (λ) were measured. The waviness (*w*) was calculated by comparing the amplitude and the wavelength of the specimens ($w = A/\lambda$).

3. Results

3.1 Wave-like figures

From the vibrational properties measurement results (Figure 1), it can be seen that there is a strong correlation between internal friction and specific modulus for sycamore maple wood. It also needs to be noted that the specific modulus of wavy maple wood is lower while its internal friction is higher than those of non-wavy maple wood.

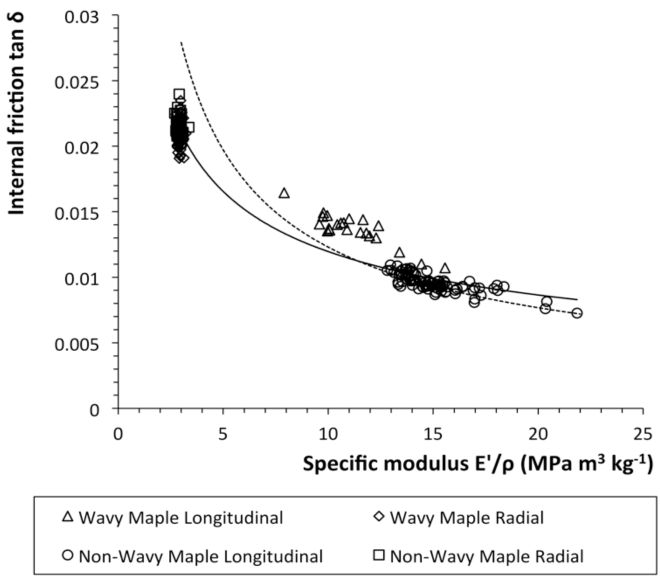

Figure 1. Internal friction and specific modulus of wavy and non-wavy maple

From the scan results of splitted wavy wood, the measurement of its figures was conducted. The waviness of the figures for each specimens of the wood are different, with some having wavier figures than others (Figure 2). The MFA of wood specimens shows high correlation value with the waviness (Figure 3): the wavier its figures, the higher its MFA. It has also been known that MFA correlates strongly with physical and mechanical properties of the wood and they, in turn, affect the vibrational characteristics which are important for the suitability of wood as musical instrument materials [8]. Thus, it is implied that, from material point of view, the waviness of the wood correlate with the suitability of wood as musical instrument material and may act not merely as visual aesthetic criteria in the selection process.

For the measurements, the rays were divided into big and small rays. The big rays consist of more than two seriates and significantly larger than the small rays, which consist of only one and two seriates. It is found that the big rays' height correlates significantly with waviness (Figure 4).

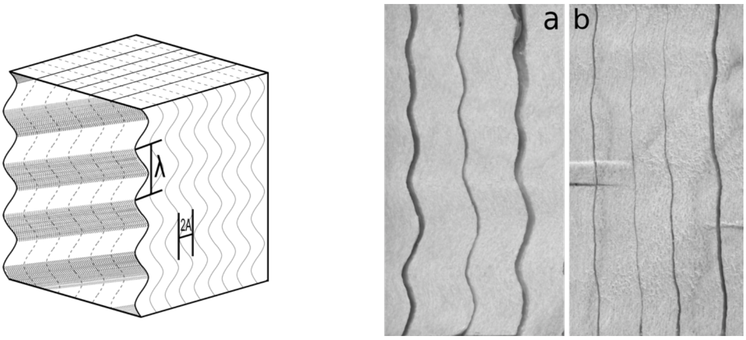

Figure 2: left: 3-Dimension depiction of splitted blocks, right: two examples of splitted wood blocks, showing different waviness, with (a) showing wavier figure than (b)

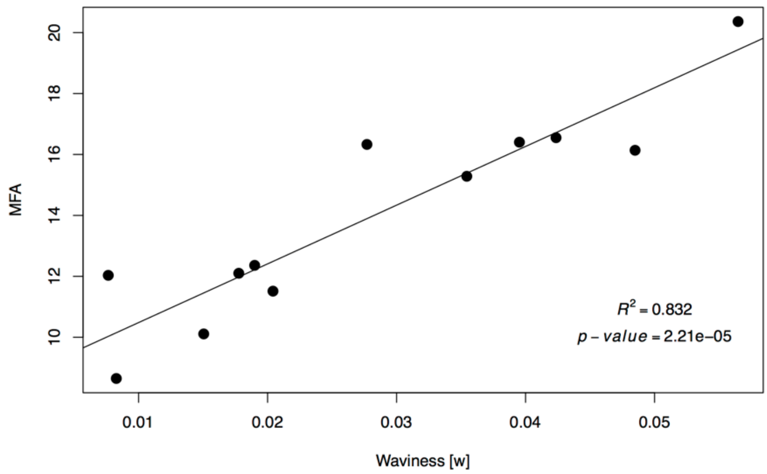

Figure 3: correlation between w and MFA

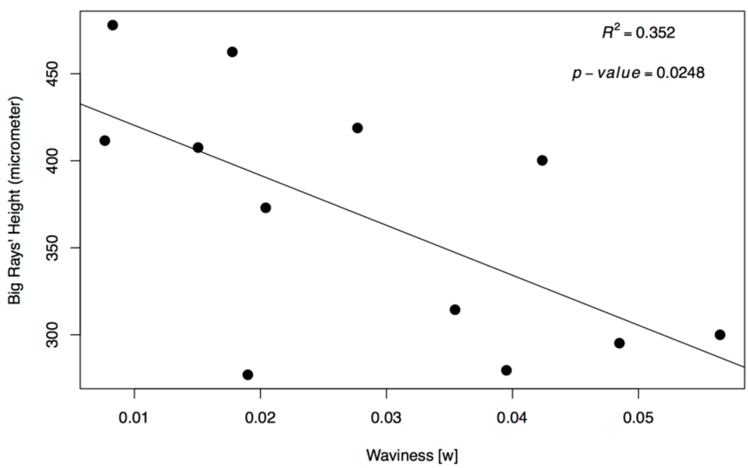

Figure 4: correlation between w and big rays' height

It needs to be noted that ray cells differ from fibres in term of physical and mechanical properties [9]. The variation in ray cells dimensions thus will lead to different composition of fibres and rays within a wood, and it is possible that these differing compositions will lead to variation in wood physical, mechanical, and vibrational properties.

Acknowledgement

The authors would like to acknowledge Daniel Guibal, Alban Guyot, Febrina Dellarose Boer, and Emma Guillon from CIRAD and LERMaB for their assistance and hospitality during the course of this research, Dr. Joseph Gril from LMGC for his guidance, the administrations of AgroParisTech and Bogor Agricultural University for their administrative and academic support, and CampusFrance and Ministry of National Education of Indonesia for the scholarship and financial support.

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