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INFLUENCE OF PHYSICAL PARAMETERS OF SOUNDBOARD WOOD ON THE GUITAR SONORITY

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INTRODUCTION

The guitar makers have always made use of spruce from Europ to build soundboards. They have been recently interested in an other essence: The western Red Cedar from North America. The soundboard wood is most important for the instrument sonority, that is why the guitar maker carefully chooses his woods according to traditional and empiric methods.

The purpose of this study is to extract, from physical measurements on woods, significant parameters which give some informations on the soundboard acoustical behaviour.

Which tests on wood does the guitar maker use in his workshop ?

1) When he taps on the soundboard with the index, he looks for a resonance frequency, the sound propagation speed and the sound damping in wood.

2) When he bends the board longitudinally and radially, he estimates the respective stiffnesses.

3) He chooses boards with straight fibers and a fine grain ; this makes the sound propagation better. This tests, usually used by the guitar makers, give qualitative informations on the resonance frequency - the damping - the stiffnesses - the density - the sound propagation speed - the wood structure.

The aim of my work is to make quantitative measurements using three experimental methods in laboratory :

1) the ultrasonic method measures the propagation speeds in the three directions (V_L - V_R - V_T).

2) The resonance method gives the longitudinal and radial flexion modulus (E_L - E_R) and also the sound damping in wood (Q)

3) The microdensitometry method measures the different components of density.

The test pieces of investigated woods have been extracted from twelve soundboards in spruce wood and twelve others in western Red Cedar wood. These woods of a high quality have been selected by D. Friederich, guitar maker, who had built instruments with these woods before and noted their sound quality. Finally the interpretation of these measurements includes three points :

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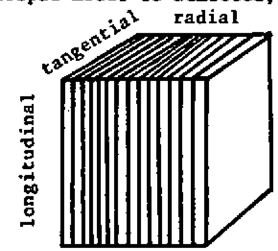
1) A comparison between the wood essences (spruce and western Red Cedar).

2) Relations between the wood structure and its mechanical properties.

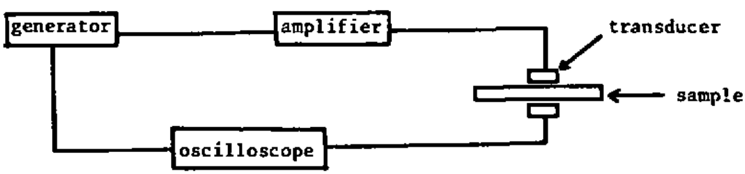
3) Relations between the measured physical parameters and the soundboard acoustical behaviour on the finished instrument.

I - PRINCIPLES OF MESUREMENT

In the wood study, the orthotropic model is admitted, so the three anisotropic directions are considered.



a) The ultrasonic method



One megaherz frequency ultrasonic wave is provided by a generator. The transducers are coupled with the sample by a resin. The time of wave propagation is read on the oscilloscope and it's possible to find the propagation speeds in the three directions (V_L - V_R - V_T).

Average values :
unity = 10^3 m/s

Essence	V_L	V_R	V_T
Spruce	5,5	1,7	1,9
Western R Cedar	4,8	1,8	1,9

b) The resonance method

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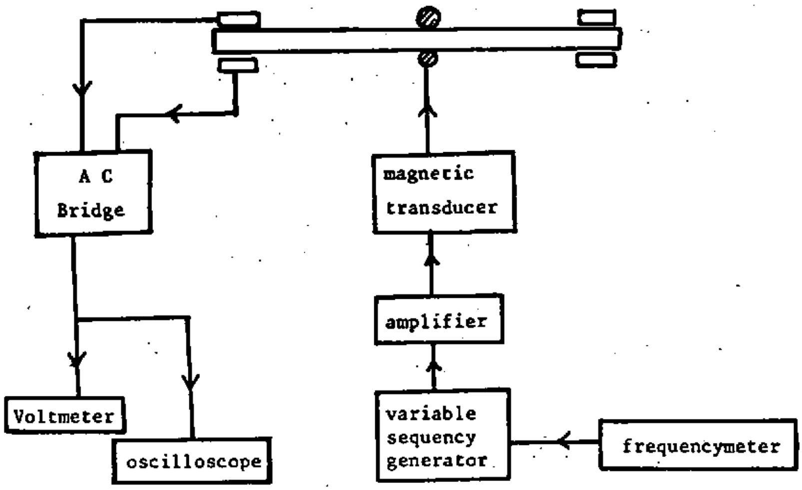


This experimentation allows to calcule the longitudinal and radial flexion modulus and also the damping coefficient or Q-value.

The sample bar, with rectangular cross section, is clamped at one end. To be made susceptible to magnetic fields, a small ferro-magnetic mass is glued on the sample in front of the transducers. Then the sample is excited in vibration with a variable periodic force. Measurements are made at the different resonant frequencies on the oscilloscope. The real part, E', of the dynamic modulus of elasticity can be found by the formula :

$$E' = 48\,\pi^2 \rho \left(\frac{l^2}{h} \times \frac{fn}{kn}\right)^2 \qquad \text{Unity = dyne/cm}^2$$

(ρ = density, l = the active length, h = the thickness, kn = coefficient depending on the boundary conditions of the bar).
By measurement of the bandwith (-3dB from the maximum), we determine the Q-value : $Q = \frac{f_0}{\Delta f}$.

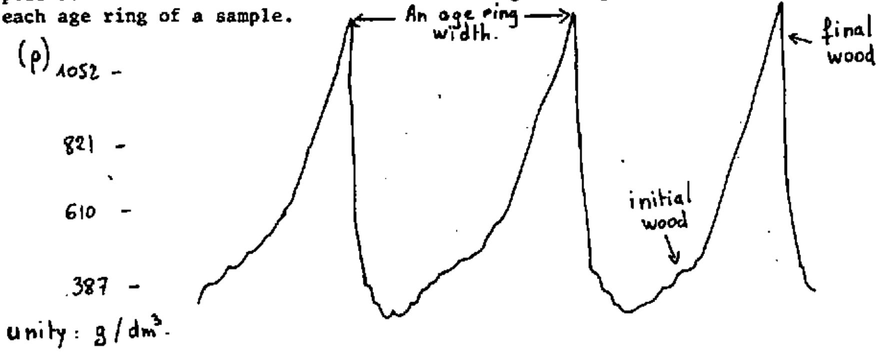
Average values :

Essences	E_L	E_R	Q_L	Q_R
Spruce	12,4	0,7	318	135
Western Red Cedar	7,8	0,3	461	167

c) Method of microdensitometry

On a longitudinal section, a piece of wood presents an age ring for each growth year. In each age ring, we distinguish a proportion of soft wood (initial wood) and a proportion of hard wood (final wood).

Sample of 1,5 mm thickness are X-rayed. More the ligneous matter is dense and more the X-rays are stopped. So, on the film , the light density regions appear as dark surfaces. The microdensitometer gives a graphic representation of each age ring of a sample.



These graphes allow to measure: the age ring width - the minimal and maximal densities - the average density-the proportion of final wood.

II - INTERPRETATION

a) Comparison between the two essences

parameters	spruce	western Red Cedar	Unities
ρ	0,46	0,39	10^3 kg/m³
E_L	12,4	7,8	10^4 daN/cm²
E_R	0,7	0,3	10^4 daN/cm²
E_L/E_R	23,2	33,4	—
V_L	5,5	4,8	10^3 m/s
V_R	1,7	1,8	10^3 m/s
V_T	1,9	1,9	10^3 m/s
Q_L	317,8	461,5	—

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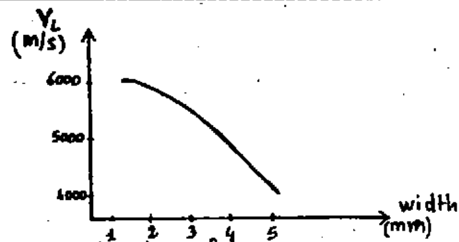
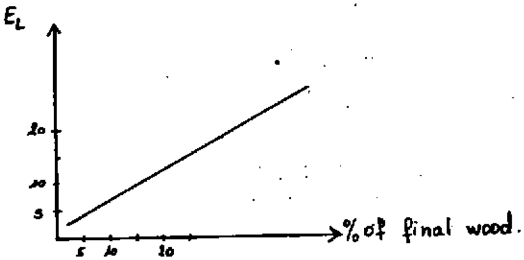
The western Red Cedar wood is lighter, more longitudinally an radially flexible than the spruce wood. In the western Red Cedar, the sound propagation speed is longitudinally smaller. And the damping coefficient is higher for it. With regard to sound quality, the guitar maker verifies that an instrument, with a western Red Cedar soundboard, gives a longer, softer, more full-bodied sound than a guitar with a spruce soundboard.

b) Relation between the wood structure and the mechanical properties



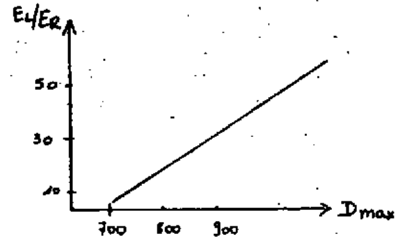
The variations of the longitudinal speed V_L in terms of the age ring width.

When he chooses spruce or western Red Cedar boards with a fine grain, the guitar maker increases so the longitudinal propagation speed (V_L).



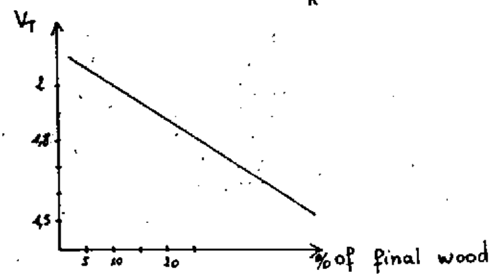
The variations of the elasticity modulus E_L in terms of final wood

More a soundboard has age rings with a strong purcentage of final wood, and more the longitudinal modulus of elasticity is high.



The variations of the ratio E_L/E_R in terms of the maximal density.

When the final wood density increases, the ratio E_{L/E_R} increases also.



The variations of the tangential speed in terms of final wood.

More the purcentage of final wood is high and more the tangential propagation speed is low.

C) Relations between the measured physical parameters and the guitar maker's judgment

- Among the twenty four built guitars, the guitar maker mentions eight instruments which present a good sound length. These instrument soundboards have the highest Q-value.

We can see that the wood Q-value directly informs the sound damping for the finished instrument.

- The modulus of elasticity (E_L) has a great influence on the guitar sound sweetness. But here it shoud be hoped to understand well the combinaison of two elasticity modulùs E_L and E_R on the sonority.

CONCLUSION

This unfinished study shows that it's possible to explain what the luthiers research in choosing their resonant woods. It especially allows to establish relationships between physical measurements on wood and sound results on finished guitars. At the end, we might be able to extract quantitative parameters on woods so that the luthiers and the wood sellers know the acoustical behaviour of soundboards that they select.

ACKNOWLEDGMENTS

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