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ACOUSTICAL AND MECHANICAL INVESTIGATIONS OF WOOD MATERIALS

A. H. Khafagy
Physics Department,
Faculty of Science, Monofia University.

ABSTRACT

The magnetostrictive delay line technique is used to investigate internal friction Q^{-1}*, as elastic moduli in different wood materials. The tested woods are camphor, morus alba, and azedarach trees. Measurements were carried out, for each wood, in two principal directions, the longitudinal direction and the other radial one. However, the results obtained for internal friction and elastic moduli were different, not only, for the worked woods, but also for the different directions in the same wood and confirmed the anisotropic character of wood structure.*

INTRODUCTION

Wood as a biomaterial consists essentially of zylem (i.e.wood tissue)cells which have their walls made up of spirally wound fibres of cellulose embedded in a stiff lignin (the chief non-carbohydrate constituent of wood) matrix (1). A simple diagram illustrates the wood directions is shown in fig. 1, where the annular rings indicate the difference in the character of spring and summer growth.

The structure of wood is orthotropic (2). It has a longitudinal axis parallel to the grain, a tangential axis tangent to the annular growth rings, and a radial axis perpendicular to the grain and the growth rings. Wood properties have provided man with an invaluable medium for constructional vork where the applications depend on ease of working a material, or, its durability and its presentable surface finish. Although vood properties are affected by moisture, it has freedom from rust and corrosion.

Acoustical and mechanical properties of wood, e.g. sound wave velocity, sound wave attenuation, or, damping and elastic moduli have been studied by several workers (3 - 9). But investigated woods were beech, tulip, spruce, cedar, fir, oke, and pine.

The purpose of this work is to extract, from acoustical measurements on some Egyptian woods, significant parameters which give informations on their mechanical behaviour. The longitudinal elastic modulus as well as the internal friction will be measured for camphor, morus alba, and azedarach wood materials.

EXPERIMENTAL

Different types of dry wood materials are tested in the present work. The investigated woods are road trees which involve camphor, morus albe, and azedarach. Strips of approximate equal dimensions (6 X 1.5 X 0.5 cm) were cut from these trees with their main lengths are aligned either along the longitudinal direction or in the radial direction of tested wood specimen respectively. These strips were used for determining the longitudinal elastic modulus and internal friction by exciting them along their lengths into their longitudinal resonant modes of vibrations.

The magnetostrictive delay line technique described previously (10, 11) in detail is used in these investigations. In this system, a generated burst of mechanical oscillations is used to excite each tested specimen at either the natural frequency or one of the harmonic frequencies of the specimen. This technique is characterized by a resultant signal echo which recorded by the system and is schermatically shown in fig. 2. The parameters shown in fig. 2, are used to calculate the internal friction, Q^{-1}, according to the following equations (10),

$$\frac{Q_c}{Q_m} = \frac{A_o + A_\infty}{A_o - A_\infty} \qquad [1]$$

and

$$\frac{\pi N}{Q_c} = \frac{\ln(2/[1-x])}{1 + x} \qquad [2]$$

Where Q_c and Q_m are the coupling and material Q-factors respectively.

The longitudinal resonant modes of vibration of each tested specimen were excited by cementing it with the remote end of the delay line wire. The corresponding resonance frequencies were detected. For a strip of length L and width W the phase velocity C_p is related to the resonance frequency F by

$$C_\rho = \frac{2LF}{n} \qquad [3]$$

Where n is the mode order number.

The longitudinal elastic modulus E of the test specimen can be found by using the equation

$$E = V^2 \rho \qquad [4]$$

where ρ is the density which was determined by weighing regular shape (parallelopiped) samples from the studied woods under the same humidity condition (about 60% moisture content). Also, V is the longitudinal rod velocity of sound waves propagation.

RESULTS AND DISCUSSION

1- Elastic Moduli of Wood.

Figs. 3, 4, and 5 show the variations of the longitudinal phase velocity C_p with the width-to-wave length ratio W/λ in the longitudinal and radial directions for tested camphor, morus alba, and azedarach woods respectively. The rod velocities V_L and V_R in both the principal longitudinal and radial directions respectively, can be determined (12, 13) by extrapolating the curves, as shown in the figures, and finding the out-off with each phase velocity axis. Thus, the elastic moduli E_L and E_R for longitudinal and radial directions can be found by using equation [4].

The experimental values for density of wood, sound waves velocities, and elastic moduli are shown in table 1. These values observed here in the present work, for sound velocities, are in great consistent with those obtained previously (4, 5, 7) on other woods. However, all observed results show that sound seems to propagate, about two times faster in the longitudinal

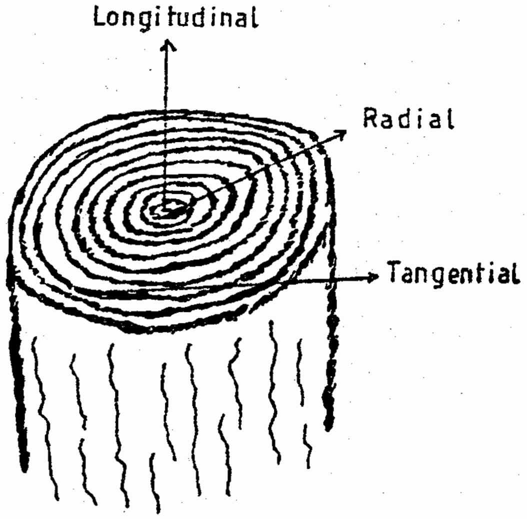

Fig. 1. A sketch shows the directions of wood.

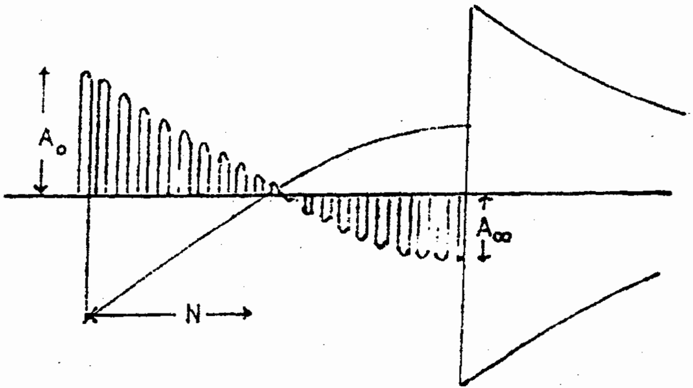

Fig. 2. The measurable parameters of the echo-signal A_o: initial amplitude, A_∞: steady state amplitude, and N: number of oscillations to cross-over.

direction along the fibres than in the other radial one. This may be due to the existence of the different growth rings in the radial direction of wood. These growth rings oppose the waves propagating normal to the fibres in a similar way like grain boundaries in polycristals, and, hence a smaller values for wave velocity.

Also, being E_L is greater than E_R, as observed here, reflects that specimens cut with their axial lengths coincident with the longitudinal direction of wood are greatly more stiff than those whose axial lengths are aligned in the radial direction for all tested woods.

2- Internal Friction of Wood.

Table 2 shows the calculated values of internal friction at the room temperature ($\approx 25^\circ C$) in both the longitudinal Q_L^{-1} and radial Q_R^{-1} , directions for the tested wood materials.

As shown in the above section, the calculated velocities in longitudinal direction, along the fibres, were larger than those obtained in the radial direction. This suggests that the damping of sound wave (or the internal friction) values will be smaller in the longitudinal direction than in the radial one. This has already been observed for all tested woods as was expected and observed previously (4) for spruce and western red cedar wood materials.

CONCLUSION

Because of the growth of wood is mainly controlled by nature, therefore, wood structure is not the same for different woods and hence different densities are existed. However, the variation ofthe measured properties in this work for the different directions of the same tested wood confirms the anisotropic nature of wood.

In spite of, few woods were worked in the present work, but it can be seen from the tabulated results of Q^{-1}, the type of wood among them, which could be used as a good absorber for mechanical vibrations by preparing boards in the suitable direction. Also, what direction should the board be cut to be more stiff and resistent for applied mechanical loads in different applications.

REFERENCES

1 -T.J.Lewis and P.E.Seker, Science of materials. George G.Harrap and Co. Ltd., pp 178 -79, (1970).

2 -L.M.Perelygin, Wood Handling, in Russian Cosloshumizdat (1949).

3 -E.Futada, and M.Date, Effect of temperature on piezoelectricity in wood, J. Polym. Sci., C (23), pp 509 - 517, (1968).

4 -D. Douau, Influence of physical parameters of soundboard wood in the guitar sonority. Proc. of the Institute of Acoustics pp 73 - 79 (1983).

5 -I.D.J. Lee, Ultrasonic pulse velocity testing considered as a safety measure for timber structures. 2nd Symp. of NDT, Spokan, Wash., USA, pp 185 - 205, April (1965).

6 -K.A. McDonald, Applications of ultrasonics in the wood industry. Ultrasonic Intl., Austria, 15 - 17 May, Conf. Proc., IPC (1979).

7 -V. Bucur, The real part of the complex elastic constants of wood by ultrasonic velocity method. Proc. of the Institute of Acoustics, (1983).

8 -V. Bucur, and R.Archer, Elastic constants of wood by ultrasonic method. Wood Science and Technology, (1983).

9 -C.A.Wert, M.Weller and D.Caulfield, Dynamic loss properties of wood. J.Appl. Phys., 56 (9), pp 2453 - 58, (1984).

10-J.F.W.Bell, and J.M. Felmore, An instrument for internal friction measurement at high temperatures. J. Phys. letters (E) Sci. Instruments, Vol.10, pp 1145 - 49, (1977).

11-A.H. Khafagy, Acoustical and mechanical investigations on metallic and dielectric media. Ph.D. Thesis, University of London, (1985).

12-P.A.Kapranose, Ph.D. Thesis, Dept. of elect. and electro. Eng., University of Aston in Birmingham, (1982).

13-A.H.Khafagy, and R.W.B. Stephens, Some acoustic measurements in biomaterials. Material Properties and Stress Analysis in Biomechanics. The Institute of Phys. In Colloboration with the Biological Engineering Society. Brunel University, Uxbridge, 23-24 April, (1985).

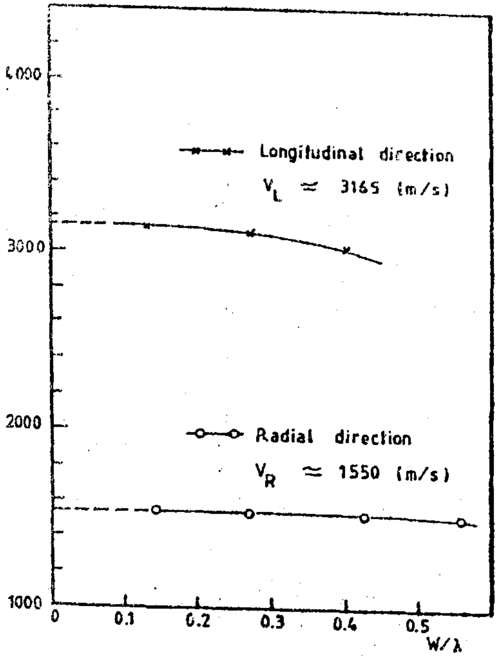

Fig.3 Variation of phase velocity with width to wavelength ratio in camphor wood.

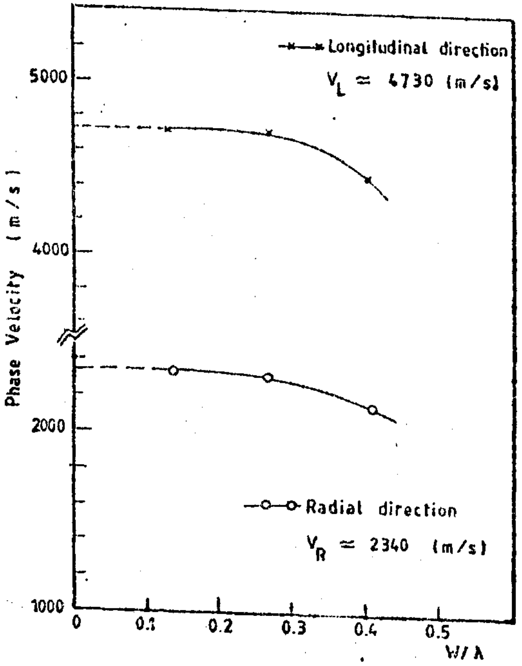

Fig.4 Variation of phase velocity with width to wavelength ratio in morus alba wood.

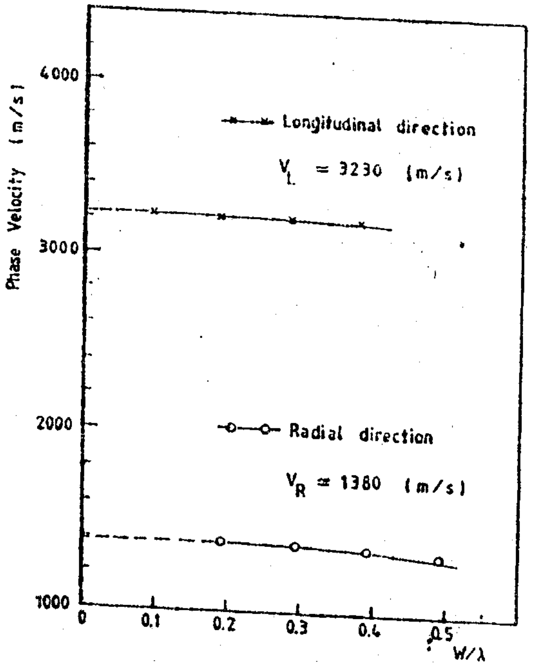

Fig.5 Variation of phase velocity with width to wavelength ratio in azedarach wood.

Table 1. Measured values of densities, sound velocities (V_L ,and V_R) in the longitudinal and radial directions . and the corresponding elastic moduli (E_L and E_R) for illustrated woods respectively.

Tested wood	ρ (kgm/m^3)	V_L (m/s)	E_L (N/m^2)	V_R (m/s)	E_R (N/m^2)
Camphor	761.9	3165	0.76×10^{10}	1550	0.18×10^{10}
Morus Alba	573.8	3230	0.60×10^{10}	1380	0.11×10^{10}
Azedarach	549.6	4730	1.23×10^{10}	2340	0.30×10^{10}

Table 2. Measured values of internal friction Q_L^{-1}, Q_R^{-1} in the longitudinal and radial directions of investigated woods respectively .

Tested wood	Q_L^{-1}	Q_R^{-1}
Camphor	7.26×10^{-3}	6.78×10^{-3}
Morus Alba	6.49×10^{-3}	8.43×10^{-3}
Azedarach	2.46×10^{-3}	3.74×10^{-3}