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APPLICATION OF MODAL ANALYSIS ON THE BEHAVIOUR DIAGNOSIS OF LIGNOCELLULOSES PLATES

Stanciu Mariana Domnica, Curtu Ioan, Rosca Ioan Calin
Transilvania University of Brasov
Department of High-Tech Product for Automotive
B-dul Eroilor 29, Brasov, cod 500036
Romania

ABSTRACT
This paper focuses on the modal analysis of the lignocelluloses plates using simple but advanced method to determine the damping coefficient and fundamental frequencies of lignocelluloses plates. First it had been measured the physical in terms of geometrical sizes, mass, moisture contents, than it had been analyzed the dynamical behaviour of the plates at free vibrations, using the impact hammer for light structures and a specialized soft to determine the damping coefficient and natural frequencies which characterized the wood based plates. Finally, the results obtained with both methods were compared to the ones obtained by other researchers in this field.
Keywords: free vibrations, damping coefficient, fundamental frequency, lignocelluloses plate

1. INTRODUCTION

One of the main objectives of sustainable development is based on using and recycling waste. Lignocelluloses composite materials from different structures (plates, beam, solid) are made from sawdust, fibres, wood chips with different sizes, all being residues resulted from primary and secondary wood processing. Mixture of the resin and matrix leads to obtain materials with new properties and with different statically and dynamical behaviour. The acoustic qualities of a mechanical structure are intrinsically linked to the material they are made of and also linked to own elastically properties. The wood’s behaviour under the acoustic waves depends on the one hand on the sound energy which makes contact with it and on the other hand it depends on the nature and the state of the wooden material, respectively on the macro and microscopic structure of the wood – the structure of the cellular membrane, the fibres’ dimensions and cohesion, the presence of some own chemicals, the wood’s humidity, the temperature of the wood, the elastically properties, and it also depends on the structure’s layout in proportion to the sound source (longitudinal, transversal, radial, tangential, complex) [9, 13, 14] .

Depending on moisture content, microscopic structure, sized (thickness), section, wood and lignocelluloses materials can be used in applications that are designed to isolate noise and vibrations (sound absorbing panels in civil, social, cultural, industrial, automotive, paving, etc.) or the construction of musical instruments.

2. OBJECTIVES OF PAPER

This paper presents results of theoretical and experimental investigations on the dynamic behaviour of lignocelluloses plates in terms of natural frequency and damping coefficient. The objectives of this research are: presentation of the equipment and the procedures of impact hammer method, determination of: logarithmic decrement, damping ratio and natural frequency of composite plates, comparison between the theoretical results obtained with FEM and experimental ones.

3. METHOD AND MATERIALS

The method used consisted of hitting plate (structure) at central points of plate with a *hammer impact* for light structures. The response of structure to vibrations has been captured by means of four accelerometers (measuring on z direction) located in symmetrically points of the plate.

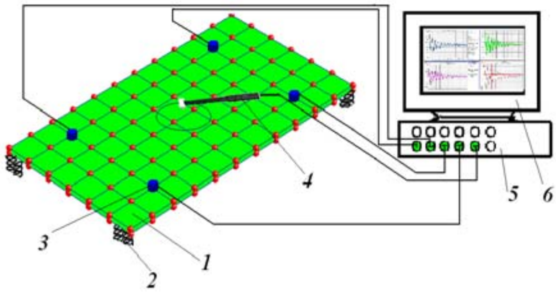

Figure 1. The experimental set-up

The captured signal was displayed with Pulse soft and the primary data were processed with ME' Scope VES 4.0 software. The experimental stand was built as it can be seen in Fig. 1. Each plate (1) was freely supported on a foam device (2) and hit with impact hammer type B & K 8204 (4) in central point of plate. The vibrations of plate were captured with four accelerometers type B&K 8320 (3) and transmitted to Pulse hardware and displayed with Pulse soft. A work program in Pulse soft was developed to capture and processing the experimental data [14]. The connections of experimental set-up has been configured, the types of measurements and implicit functions (Time, Fast Fourier Transform, Fourier Spectrum, Complex Time) were established. The results of measurement were displayed in a different task of soft and saved as files for processing with ME' Scope program [10, 12]. The plywood and solid wood plates with geometry as in Figure 1 were tested. Before the effective tested, it was measured the moisture content of wood and the thicknesses of plates in 7 points, using the ultrasound moisture meter type Merlin PM1-E [14] . In Table 1 are summarized the average values of geometrical sizes, moisture content, density and Young's modulus from literature of the tested samples [3, 4, 5, 6].

Table 1. The physical features of tested plates

Materials of plates	Thicknesses h [mm]	Length L [mm]	Width l [mm]	Moisture content U [%]	Density ρ [kg/m^3]	Young's Modulus E_L [MPa]
Sample 1 Spruce - plywood	2	530	415	8.7 %	450	14500
Sample 2 Spruce –plywood	2	530	415	7.4 %	450	14500
Sample 3 Spruce –plywood	2	530	415	6,6 %	510	11800
Sample 4 Spruce –plywood	2	530	415	9.7 %	540	10900

4. RESULTS AND DISCUSSIONS

First results obtained with Pulse system refer to time capture of accelerometer signals as is shown in Figure 2. It could be noticed that the dynamical behaviour of plates is governed by the damped harmonic motion. Applying the Fast Fourier Transform to the time signal exported from Pulse to ME' Scope soft, the values of natural frequencies and damping coefficient were obtained as it can be seen in Figure 2. It is found that the analyzed plates made from different species and with different composition present multiple natural frequencies. Depreciation of the internal mechanisms of wood plates are dependent on their own frequencies, estimating the specific characteristics is also difficult because of the non-isotropy of wood species, density and wood as being an non-homogeneous material. Unlike the homogeneous and isotropic materials, for wood is used the relation presented below applied on experimental results [1, 2, 3]. Thus, internal friction is expressed by the logarithmic decrement or quality factor of vibration damping, Q. In the case of forced vibration, the logarithmic decrement is calculated with relation (6.1) - after Beldeanu [1, 2, 3]:

$$\delta = \pi \frac{\Delta_f}{f_r} = \pi \frac{f_2 - f_1}{f_r} \qquad (1)$$

where f_r is the resonance frequency in Hz and f_1, f_2 - frequencies corresponding vibration amplitudes, $A_{1,\ 2} = 0,707 * A_{max}$.

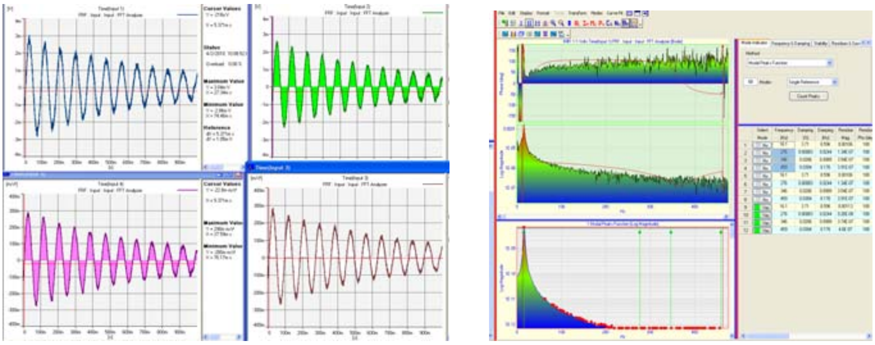

Figure 2. Acquisition and visual display of output signal in terms of time capture and FFT

The value of internal friction depends on the moisture content, species, anisotropic direction, size and structure of sample (beam, plate), the regularity and continuity of the wood structure, the mode of fixation and method of investigation. It was noticed that average values of fundamental frequency and damping ratio depending on the particular characteristics of wood, even in the same species. From this point of view, the wood and all lignocelluloses materials are versatile materials being used for acoustic insulating when the damping ratio and implicit the acoustic loss have big values (more than 0,02), or for resonance values in musical instruments construction [7,8].

Table 2. Measured and calculated values of damping ratio

Sample	*Mass m [Kg]*	*Experimental Damping Ratio ζ (Average values)*
Sample 1 Spruce	0,281	0,018738
Sample 2 Spruce	0,282	0,017050
Sample 3 Spruce	0,284	0,017958
Sample 4 Spruce	0,276	0,018475

Comparing the experimental results with literature as is shown in Table 3, it can be remarks that we obtained similarly values, using different experimental method.

Table 3. Comparison of results to the literature ones

Measurements in Longitudinal – Radial plane of wood	*Experimental Fundamental Frequency f [Hz]*	*Experimental Damping Ratio ζ*
Stanciu / Spruce plywood (h= 2 mm)	9.476	0.017632
Bucur (2006) /Sitka spruce	9.531	0,013000

5. CONCLUSION

In conclusion, the present method the presented method is an advanced variant of scientific research to study the dynamic characteristics of materials in a modern and relatively easy way. Impact hammer method involves the proper equipment, an adequate software and rigor in determination. This method of scientific investigation can be used for any type of structure and material. Regarding the experiment, both the materials of plates and boundary conditions, have a great influence on the results of measurements. In our research the acoustical characteristics of lignocelluloses plates were presented. Each species presents the own macro and microstructure, for which appreciation acoustic characteristics requires a very rigorous statistical study, which is not subject to present research. Even within the same species, there were differences due non-homogeneity sensitive material timber and method of cutting. In the vibration laboratory of the Department of High-Tech Product of Automotive have been tested other structures such as carbon fibres composite boards and fibreglass, car bodies, aircraft wings, propellers, engines, etc.

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6. REFERENCES

[1] Beldeanu, E., Pescăruş, P. "Research on the Acoustic Quality Classes of Resonance Spruce Wood of Romania", Proceedings of 10th International Symposium on Nondistructive Testing of Wood 1996.

[2] Beldie, I. P., (1965). Determinarea frecvenţelor proprii ale plăcii viorii, în vederea acordării acestora. În Rev. Industria Lemnului, nr. 4, (in Romanian)

[3] Bucur, V. "Acoustic of wood" Springer-Verlag Berlin Heidelberg New York, 2006.

[4] Curtu, I., Ghelmeziu, N. Mechanics of Wood and Wood Based Materials (in Romanian language), Ed. Tehnică, Bucureşti, România 1984.

[5] Curtu, I., Stanciu, Mariana, Itu, C., Grimberg, R., "Numerical Modeling of the Acoustic Plates as Constituents of Stringed Instruments", in Proc. of the 6th International Conference of DAAAM Baltic Industrial Engineering, ISBN 978-9985-59-783-5, Tallinn, Estonia.24-26th April 2008, p. 53-58, 2008.

[6] Curtu I, Stanciu M, Cretu N & Rosca I, "Modal Analysis of Different Types of Classical Guitar Bodies", Proceedings of the 10th WSEAS International Conference on Acoustics & Music: Theory & Applications – AMTA09, 23-25 March 2009, Prague, Czech Republic, ISBN: 978-960-474-061-1, ISSN: 1790-5095, pp. 30-34, 2009.

[7] Curtu I, Stanciu M.D., Correlation between experimental method and FEM regarding normal modes of anisotropic plates, in Acta Technica Napocensis, Seria Applied Mathematics and Mechanics 53, Vol II, 2010, Universitatea Tehnica din Cluj – Napoca, ISSN 1221-5872, pp. 229-234

[8] Dinwoodie, J. M., (1989). Wood Nature's Cellular, Polymeric Fibre-composite. The Institute of Metals North American Publication Center USA, ISBN 0-901462-35-7

[9] Pellerin R., Ross R., "Nondistructive Evaluation of Wood", Forest Product Society Madison, USA, 2002.

[10] Pierce, A. D. (1981). Acoustics: an introduction to its physical principles and applications, McGraw-Hill, New York

[11] Rossing, T., Fletcher, N., „Principle of Vibration and Sound" – second edition. Springer Science, New York, 2004.

[12] Schleske, M. (1990) Speed of sound and damping of spruce in relation to the direction of grains and rays, J. Catgut Acoustical Society, 1 (6) Series II, 16-20.

[13] Stanciu Mariana Domnica, Curtu I. (2008) Dynamical Analysis of Ligno-Cellulose Plates with Numerical and Analytical Methods, In Proceedings of 7thScientific/Research Symposium with International Participation: Metallic and nonmetallic materials MNM2008, Zenica 22-23 May 2008 (Bosnia Herţegovina), p. 551-556 pe CD, ISBN: 978-9958-785-10-8, in Book of Abstract p. 134.

[14] Stanciu M. D., Curtu I., "Using Advanced Method To Determine The Acoustical Parameter Of Lignocellulose Composite Materials", in Proceedings of the 12th International Conference AFASES 2010, organizata de Academia Fortelor Aeriene Henri Coanda din Brasov, 27-29 mai 2010, pe CD – ISBN 978-973-8415-76-8, 2010.