14th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2010, Mediterranean Cruise, 11-18 September 2010

MEASUREMENT OF RESONANCE FREQUENCY AND OTHER PROPERTIES OF LIGHTWEIGHT STRUCTURES USING ADVANCED METHODS

Curtu Ioan, Stanciu Mariana Domnica, Timar Janos
Transilvania University of Brasov
Department of High-Tech Products for Automotive
B-dul Eroilor 29, Brasov, cod 500036
Romania

ABSTRACT

This paper deals with research performed on experimental testing stand in order to determine the dynamic behaviour of the lightweight composite plates related to the forced vibrations. The plates were tested applying a harmonic excitation to the structures by means of the mini-shaker. The response of the structure to forced vibrations has been captured by means of an accelerometer (measuring on z direction). The captured signal was amplified and filtered through a conditioner, then was sent to the acquisition board connected to the computer. The signal capture and display were achieved through the Pulse soft. The complex used methods provide us with the modal shapes and the characteristics of the frequency transfer function for tested structures.

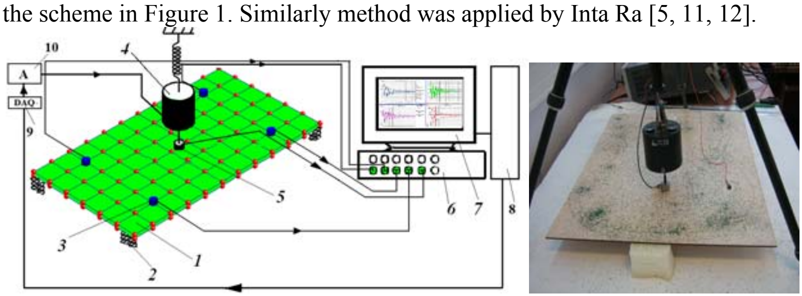
Keywords: resonance, wood, plate, vibration.

1. INTRODUCTION

Lignocelluloses composite materials are made from veneers, sawdust, fibres, wood chips with different sizes, most of them 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 damping properties of these materials are generated by their structure: continuous and discontinuous randomly oriented short fibres [6, 8, 9, 11]. Knowing the acoustic properties of materials and their dynamic behaviour in terms of frequency characteristics is very important for prediction of their proper use. The lignocelluloses composite plates are used in structures with different functions: resistance, aesthetic, phonic protection, acoustic amplification etc. In the present research were investigated the plywood plates obtained from different wooden species. The objectives of this research are: presentation of the equipment and the procedures of forced vibration method, determination of: resonance frequency, damping coefficient and vibration mode of lignocelluloses plates.

2. METHOD AND MATERIALS

The experimental set-up consisted of a vibration mass (mini-shaker) mounted on a freely supported plate (sample) with rectangular geometry (1). The mini shaker (4) was excited by a harmonic excitation from generator. This dynamical force produces in plate bending vibration. Were generated different values of excitation force in terms of which were amplified by means amplification device (10). The response of the structure to forced vibrations has been captured by means of accelerometers (measuring on *z* direction) (3). The input signal was measured with a force transducer (5). Both signals were transmitted to Pulse hardware (6) and displayed with Pulse soft (7). A work program in Pulse soft was developed to capture and processing the experimental data. The experimental stand was built according to the scheme in Figure 1. Similarly method was applied by Inta Ra [5, 11, 12].



3.

Figure 1. Experimental

The plywood from different species (spruce, hornbeam, lime) with rectangular 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. In table 1 are summarized the average values of geometrical sizes, moisture content, density and Young's modulus from literature of the tested samples [1, 2, 3, 4].

Table 1. Physical properties of sample used for experimental test

Materials of plates plywood	*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	2	530	415	8.7 %	638,781	12000
Sample 2 Spruce	2	530	415	7.4 %	641,054	12000
Sample 3 Spruce	2	530	415	6,6 %	645,601	12000
Sample 4 Spruce	2	530	415	9.7 %	627,415	12000
Sample 5 Hornbeam	2	530	415	7.0%	795,635	16000
Sample 6 Lime	2	530	415	8.9 %	709,252	13300

In Table 2 are presents all values of input signal in terms of frequency excitation, tension, intensity.

Table 2. Input Data

Excitation force [Hz]	110	146	196	246	329	413	440	588	720	980
Tension [V]	1.8	1.8	1.2	1.2	1.2	1.5	2.1	3.5	3.1	1.5
Intensity [A]	0.5	0.5	0.3	0.3	0.3	0.3	0.4	0.7	0.7	0.3

3. RESULTS AND DISCUSSION

3.1. Chladni or Nodal Line Patterns

The modal shapes of top plates knowing as Chladni pattern are given by the distribution of the significant nodal lines on the surface of structure. The nodal line represents the points or areas which remain in equilibrium position during the vibration. During vibrations, each pattern of strutting system characteristically has nodes and antinodes at various locations on the body of the guitar [6, 10]. There are many methods to determine the Chladni patterns: non contact - holographic interferometer techniques and with contact – using powder covered of plate. In this research we used the second technique as it can be seen in Figure 2. Comparing the obtained results (Figure 2), it can be noticed that there are a lot of similarities regarding the modal shapes of low frequency (110, 146, 196 Hz). With increasing of frequency, the Chladni patterns [4] become more complex and different from a structure to another. Reviewing the modal forms obtained, the following aspects were found:

- when the frequency is increased, modal shapes become more complex and tend to be similar regardless of species;

- the symmetry of the modal shapes depends on the symmetry of the wood microstructure;
- Chladni figures provide us with useful information about the capacity of the plates and of the wood species to respond at different excitation frequencies; walnut and mahogany respond better to low and medium frequencies, compared to cherry, maple and alder whose dynamic behaviour is favoured by higher frequencies;
- the modal shapes differ with rigidity of plates which are made by mechanical and physical properties of materials, stiffening elements applied on plate;

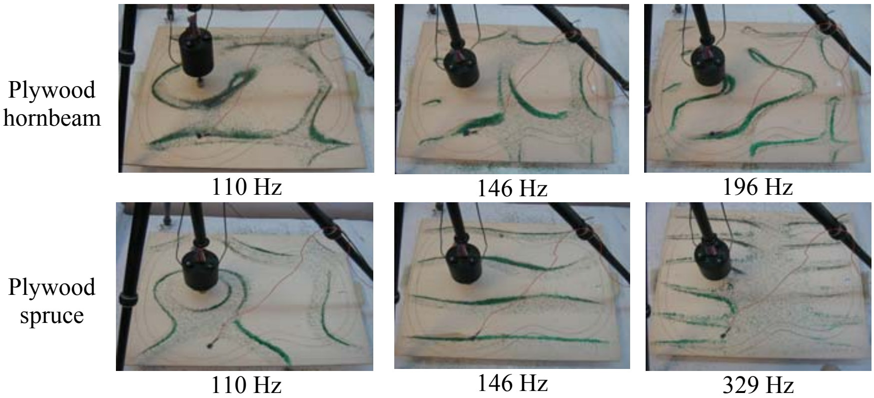


Figure 2. Chladni Patterns captured during experiment in case of plywood plates made from hornbeam and spruce

3.2. The Fourier Analyses

The signals from the force transducer and accelerometer were captured with Pulse soft. The functions as Fast Fourier Transform (FFT) for displayed measures were used [4, 9]. It could be noticed that dynamical behaviour of plates regardless of wood species is governed by the same harmonic law as excitation force. Regarding the resonance frequencies, in spite of the same values of harmonic excitation which were applied during the experiments, it was recorded different resonance frequencies for plates made from different wood species. In Figure 3 is display the FFT in terms of magnitude of signals captured with accelerometers placed on plates. The peaks represent the resonance frequencies; usually the first value of resonance frequency corresponds with excitation frequency.

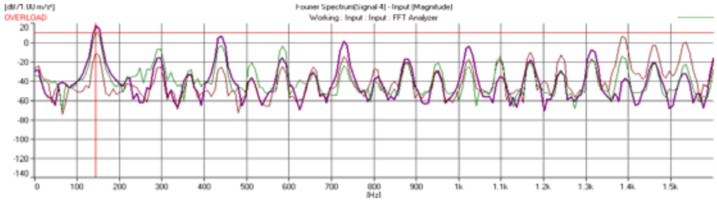


Figure 3. Fourier spectrum in terms of magnitude

Processed data from this type of analyse it was obtained all resonance frequency of each tested plate. In terms of power of acoustic radiation, spruce behaves most uniform and homogenous regardless of the excitation frequency, unlike the other species whose behaviour differs with frequency. The excitation frequency represents one of the most important factors of the plate dynamical behaviour in terms of values, intensity and duration. When the excitation frequency is identical with natural frequency, the resonance phenomena appears which leads to various responses [5,7]. One of them can be an advantage for the structure as is the case of guitar's plate or can cause numerous faults and defects. The resonance frequency depends on a series of factors: the plate's shape and dimensions, the contour conditions, the plates' structure, the material's anisotropy, the approached research method.

The increasing of the plate's width and rigidity leads to the increasing the resonance frequencies. In case of plywood obtained from spruce veneers the low-limit frequency varying in the interval 40-65 Hz. Optimum combination of these factors correlated with the utilization conditions of the acoustic plates can contribute to an increasing quality of the structure, which the plates are integrated in [11, 12].

4. CONCLUSION

The paper focuses on experimental method based on advanced equipment. Research on dynamic behaviour of plates from different wood species was investigated. The study dealt both with theoretical implications and, more importantly, with practical aspects. The dynamic phenomena of the thin plates in conjunction with geometrical, physical and micro structures characteristics of the wood species are explained.

ACKNOWLEDGEMENT

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU POSTDOC-DD, ID59323.

5. REFERENCES

[1] Bucur, V.: Acoustic of wood. Springer-Verlag Berlin Heidelberg New York, ISBN-13 978-3-540-26123-0, 173-216 (2006).

[2] Curtu I., Stanciu M. D., Motoc D.L., Diagnosis of dynamic behaviour of ligno-cellulose composite plates, in Proceedings of 14th European Conference on Composite Materials, Published by Budapest University of Technology and Economics, Department of Polymer Engineering, Budapets, ISBN 978-963-313-008-7.

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

[4] 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.

[5] Inta Ra, The acoustics of the steel string guitar, PhD Thesis, The University of New South Wales, Australia, September, (2007)

[6] Motoc Luca, D., Curtu I., A Micromechanical Based Approach for Dynamical Properties Evaluation in Case of Polymeric Composite Materials, In Proceedings of the 7th International Conference of DAAAM Baltic Industrial Engineering, 22-24 aprilie 2010, Tallin Estonia, ISBN 978-9985-59-982-2, p. 423-428,

[7] Rossing, T., Fletcher, N., Principle of Vibration and Sound. Springer Science, New York, (2004).

[8] 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.

[9] Stanciu Mariana Domnica, Curtu I.,(2009). Experimental Research Regarding the Acoustic Features of Wood Species used on Classical Guitar Construction in Proc. Of 8th Youth Symposium on Experimental Solid Mechanics, 20-23 May 2009, Gyor Ungaria, ISBN 978-963-9058-26-2, p. 64-65, pe CD ISBN 978-963-9058-27-2 (2009)

[10] 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.

[11] Stanciu M. D., Curtu I., The influences of Guitar Plates on the Vibrations of Guitar, in Proc. Of 8th Youth Symposium on Experimental Solid Mechanics, 20-23 May 2009, Gyor Ungaria, ISBN 978-963-9058-26-2, p. 24-25, pe CD ISBN 978-963-9058-27-2

[12] Stanciu M. D., Curtu I., Cretu, N., Grimberg R., Researches Concerning the Dynamic Behaviour of LignocelLulose Plates With Different Stiffening Braces, in Buletinul Institutului Politehnic din Iasi, Tomul LV (LIX) Fasc. 4, Sectia Stiinte si Ingineria Materialelor, publicat de Univ. Tehnica „Gh Asachi" din Iasi, ISSN 1453-1690, pp. 371-378