THE MODAL ANALYSIS OF PLATES MADE OF WOVEN COMPOSITE MATERIALS

Prof. dr. ing. Ioan CURTU
Universitatea „Transilvania" – Braşov
E-mail: curtui@unitbv.ro

Dr. ing. Mariana Domnica STANCIU
Universitatea „Transilvania" – Braşov
E-mail: mariana.stanciu@unitbv.ro

Prof. univ. dr. ing. Vasile CIOFOAIA
Universitatea „Transilvania" – Braşov
E-mail: ciofoaiav@unitbv.ro

REZUMAT. Lucrarea prezintă analiza modală a comportării dinamice a plăcilor din materiale compozite cu inserţii textile. Au fost analizate patru tipuri de material compozit, acestea fiind diferite prin numărul de straturi, grosime şi tipul de presiune aplicat în cadrul reţetei de obţinere. Pentru fiecare tip de compozit au fost testate cate 15 plăci (epruvete). Rezultatele au condus la determinarea frecvenţei şi a modurilor proprii pentru fiecare structură, formele proprii fiind obţinute cu ajutorul metodei elementului finit.

Cuvinte cheie: compozite cu textile, metoda elementului finit, frecventa proprie, amortizare.

ABSTRACT. The paper present the modal analysis of dynamical behaviour of plates made from woven composite materials. The four type of composite were analysed each differed one from another by number of layers, thickness and pressure. For each type of composite, 15 samples were tested. The results lead to natural frequency for each structure and modal shape obtaind using finite element method (FEM). The prediction of dynamical behaviour of composite plates plays an important role in their future application.

Keywords: woven composite, FEM, natural frequency, damping.

1. INTRODUCTION

Vibration damping of composite plates is the phenomenon that occurs as a result of sound losses of sound energy dissipated in the material being an interdependent phenomenon of internal friction (expressed as logarithmic decrement of vibrations damping), the contributions of constituents, their combination of architecture and the stages between phases [1]. Depreciation of the internal mechanisms of composite plates are dependent on their own frequencies, estimating the specific characteristics is also difficult because of the non-isotropy of materials, density and woven composite as being an non-homogeneous material [2. 3, 5]. The reinforcement of composites with woven materials leads to improved properties of composite materials in terms of acoustical, elastical and thermal properties [10].

2. EXPERIMENTAL PART

In the herein study, the laminated composite plates made of woven fabrics EWR300 with continue E glass fibres/unsaturated polyester resin and having the physical and elastically features listed in Table 1, were tested. Four types of woven composite materials were studied, being different one from another by number of layers, thickness and pressure. For each type of composite, 15 samples were tested. The experimental set-up was built as it can be seen in Figure 1 [5]. Each composite plate (*1*) was freely supported on a foam device (*2*) and hit with impact hammer, type B & K 8204 (*4*), in the central point of plate. The vibrations of plate were captured with four accelerometers type B&K 4507 (*3*) and transmitted to Pulse hardware and displayed with Pulse soft. The primary data were processed with ME' Scope VES 4.0 software. The light accelerometers weight did not affect the values of natural frequencies extracted from experimental tests. The devices used for simulate free boundary conditions are different, as it can be found in references: foam device placed on corners, or along the edges, suspended plate, elastically support for entire surface [4, 6]. After numerous tests regarding the proper type of support, was found that are negligible influences which conduct to use the foam devices placed in corner of studied plate (Figure 1) [9].

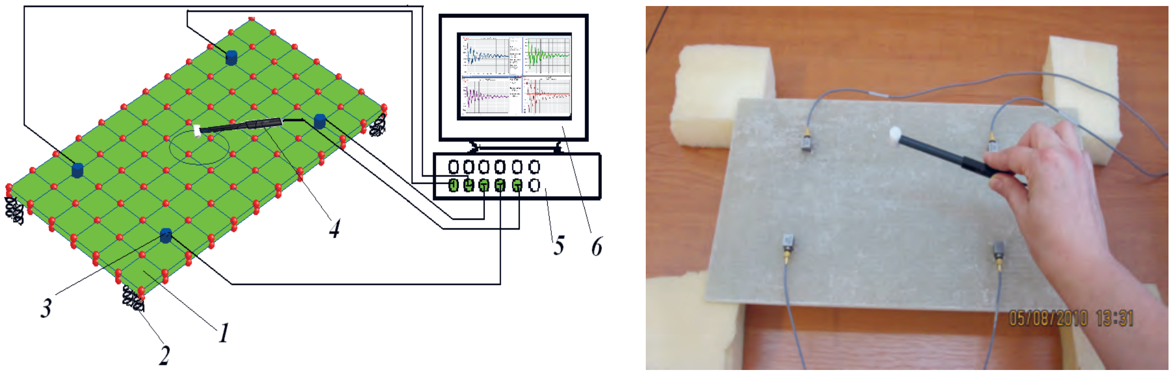


Fig. 1. The experimental set-up:
1 – studied sample; *2* – yielding seat; *3* – accelerometer(s); *4* – impact hammer; *5* – pulse hardware; *6* – pulse software.

Table 1. **Structure of composite materials**

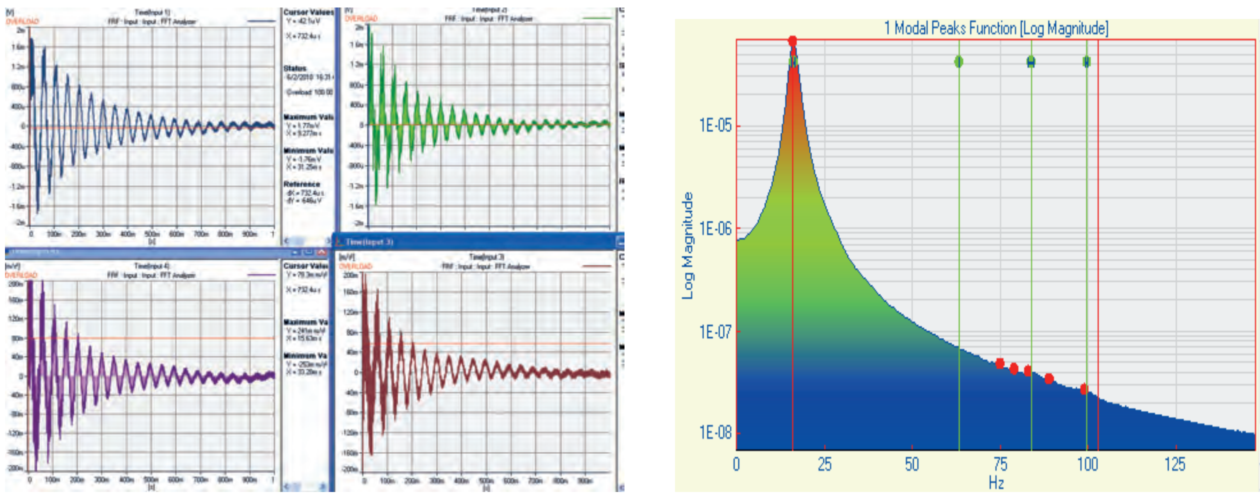
Type of composite plates	Resin	Layers/ Reinforcement	Sizes *L×l×h*	Manufacturing process
Composite type 1 (15 Samples)	Unsaturated polyester resin (Heliopol 9431)	4 layers stratimat 300 g/m^2 3 layers woven fabrics plain wave E glass fibres	400x200x4	Normal pressure
Composite type 2 (15 Samples)	Unsaturated polyester resin (Heliopol 9431)	5 layers stratimat 300 g/m^2 4 layers woven fabrics plain wave E glass fibres	400x200x6	Normal pressure
Composite type 3 (15 Sample)		6 layers stratimat 300 g/m^2 4 layers woven fabrics plain wave E glass fibres	400x200x6	Low pressure
Composite type 4 (15 Sample)		6 layers stratimat 300 g/m^2 4 layers woven fabrics plain wave E glass fibres	400x200x6	High pressure

3. RESULTS AND DISCUSSION

For each plate, four responses were captured simultaneously by means of accelerometers placed symmetrically in front of geometrical centre of the plate. The response signal was acquired during the experimental testing in terms of FFT (i.e FFT – Fast Fourier Transform) and an exponential decay, leading after some computation to the possibility of retrieving the natural frequencies and damping coefficient of composite samples (Fig. 2). The top of FFT curve represents the first natural frequency. The data in terms of natural frequencies and damping were centralized and for each composite type it was calculated the average value of frequency and damping.

Figure 3 presents the comparison of dynamical behaviour of composite in terms of fundamental frequency. It can be noticed that with increasing of thickness with 33%, the natural frequency decreased with 12%. The composite material type plays an important role in the dynamic behavior of plates, mainly on its fundamental frequency.

Regarding the damping of composite plates, it can be noticed that the damping coefficient have closely value regardless of number of layers (Figure 4). The manufacturing process in terms of used pressure can influence the behaviour of composite as it can be seen in Figure 3 and 4, case of composite *3* and *4*. In Figure *4* you can see a relatively large dispersion of damping values for tested samples made from the same composite. This phenomenon is characteristic of the dynamic behavior of composite plates, due to material anisotropy [7, 8]. Regarding the damping of composite plates, it can be noticed that the damping coefficient have closely value regardless of number of layers (Figure 4).



a) b)

Fig. 2. Example of the response signal:
a – exponential decay function; *b* – Fast Fourier Transform function.

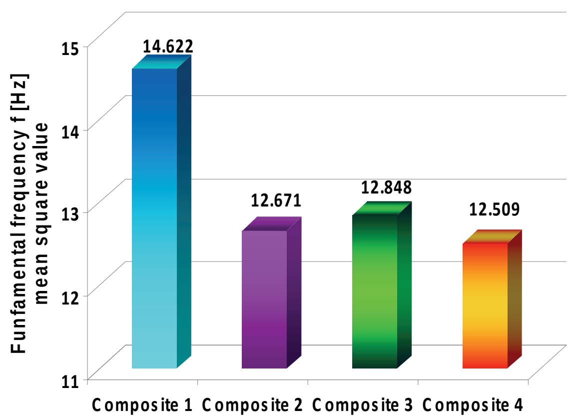


Fig. 3. Comparison between fundamental frequencies of tested composite plates.

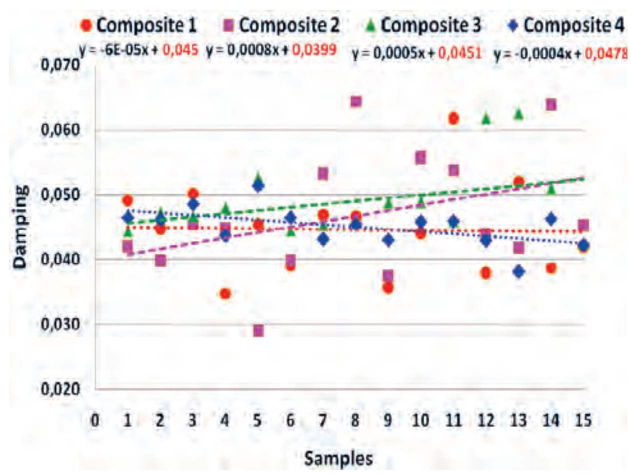


Fig. 4. Damping values of studied plates.

4. NUMERICAL ANALYSIS

The experimental results were compared with the results obtained after running some simulations based on finite element method (FEM). The plates were meshed using shell type elements with four nodes and ABAQUS as environmental software. Free boundary conditions were considered. The analysis was performed for different values of density and Young's modulus of the plate material – lignocelluloses composite has the following characteristics:

- density ρ (ρ = 600.....800 kg/m^3),
- longitudinal Young modulus E_x: (E_x = 10000... 16000 MPa);
- transversal Young modulus E_y (E_y = 5000... 9000 MPa),
- Poisson's coefficients: ν_{xy} = 0.44 and ν_{yx} = 0.028.

In Figure 5 are displayed the modal shapes for the first six modes. The modal shapes are similarly irrespectively of mechanical properties of materials, especially when values have the same size grade. Comparing the numerical results with experimental ones, it can be noticed some differences between them due to the hypothesis used in numerical modelling.

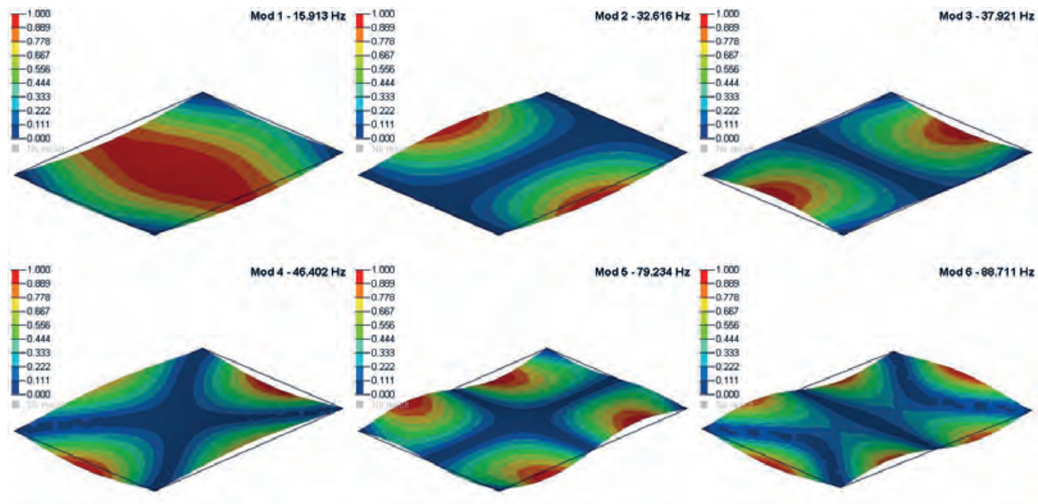


Fig. 5. The modal shape of Composite 1.

5. CONCLUSIONS

It is noted that the present method can predict natural frequencies of composite plates. The dynamical behaviour of composites depends on one hand by structure and type of fibres and on the other hands by physical characteristics such as density, thickness, manufacturing process. This experimental method re-presents a non-destructive way used to predict the dynamical behaviour of woven composite, in order to design panels or other similarly structure used in different applications such as automotive industry, soundproofing panels for highway, in concert halls architecture, sound insulation of buildings.

Acknowledgements

This paper is supported by the Sector 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.

REFERENCE

[1] **Alămoreanu, E., Constantinescu, D. M.**, (2005). *Proiectarea plăcilor composite laminate,* Bucureşti, Ed. Academiei Română, p. 11-30 (in Romanian);

[2] **Cerbu, C., Curtu, I., Ciofoaia, V., Rosca I. C., Hanganu, L. C.,** *Effects of the Wood Species on the Mechanical Characte-ristics in Case of Some E-Glass Fibres/Wood Flour/Polyester Composite Materials*, in Rev. Materiale Plastice, MPLAAM 47 (1) 2010, Vol. 47, nr. 1 –martie 2010, Bucuresti Romania, pp.109-114, 2010.

[3] **Cosereanu, C., Curtu, I., Lunguleasa, A., Lica D., Porojan M., Brenci, L., Cismaru, I., Iacob, I.,** *Influence of Synthetic and Natural Fibers on the Characteristics of Wood-Textile Composites*, Revista Materiale Plastice vol. 46, nr. 3 Sept. 2009, Bucuresti, p. 305-309, 2009.

[4] **Deobald LR, Gibson RF.** *Determination of elastic constants of orthotropic plates by a modal analysis/Rayleigh–Ritz technique*. Journal of Sound Vibration 124:269–83, 1988.

[5] **Grimberg, R., Curtu, I., Savin, A., Stanciu, M. D., Andre-escu A., Leitoiu S., Bruma A., Barsanescu P,** *Elastic Waves Propagation in Multilayered Anisotropic Composite – Application to Multilayered Lignocellulose Composite*, in Proc. of The 7th Edition of International Conference „Wood Science and Engineering in the Third Millennium", ICWSE 2009, Brasov, pp. 688-695, 2009.

[6] **Hatami, S., Azhari, M., Saadatpour, M.M.,** *Free vibration of moving laminated composite plates*, Composite Structures 80 (2007) 609–620, 2007.

[7] **Lee, C.R., Kam, T.Y.,** *Identification of mechanical properties of elastically restrained laminated composite plates using vibration data*, Journal of Sound and Vibration 295, 999–1016, 2006.

[8] **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, p. 423-428, 2010.

[9] **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.

[10] **Tran Ich Thinh, Tran Huu Quoc,** *Finite element modeling and experimental study on bending and vibration of laminated stiffened glass fiber/polyester composite plates*, Computational Materials Science, 2010.