13th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2009, Hammamet, Tunisia, 16-21 October 2009

A PRACTICAL EVALUATION METHOD OF DYNAMICAL BEHAVIOUR OF CLASSICAL GUITAR BODIES

Stanciu Mariana Domnica, Curtu Ioan, Lica Dumitru, Cretu Nicolae
Transilvania University of Brasov
B-dul Eroilor 29, Brasov
Romania

Savin Adriana
National Institute of Research and Development for Thechnical Physics Iasi
B-dul Mangeron 47, Iasi, Romania

Nastac Silviu
“Dunarea de Jos” University of Galati
Engineering Faculty of Braila
Str. Călăraşilor nr.29 , Braila, Romania

ABSTRACT
The paper presents a experimental evaluation method of dynamical behaviour of guitar bodies. In these studies different types of guitar body from the point of view of braces pattern are taken in consideration. The method consists of measuring of accelerometers signals placed on soundboard, back and side of guitar. The structures were excited with a harmonic force usinga mini-shaker. The signals were captured and processed by means of Pulse 12 system B&K. The variation of modal shapes, frequency response function and sound pressure are displayed in numerous plots. From dynamical and acoustical behaviour of each structure it is possible to predict the acoustical profile of different typologies of classical guitar.
Keywords: guitar body, dynamics, modal shape, sound pressure

1. INTRODUCTION
The classical guitar body represents the main part of acoustics function of instruments. This is made up of lignocelluloses plates which are glued on sides forming an acoustics box. Thus, the guitar body have a similarly behavior with a Helmholz resonator. The plates must have a thin thickness in order to vibrate under the exciting forces of strings. In the same time, these structures must resist to the cyclic stresses during playing. Both requirements are fulfilled by the stiffening braces glued on the top plates [1]. According with the types of guitars made up of S.C. Hora S. A. Reghin Romania in Figure 1 seven types of top plates different from the point of view of stiffening braces pattern are presented.

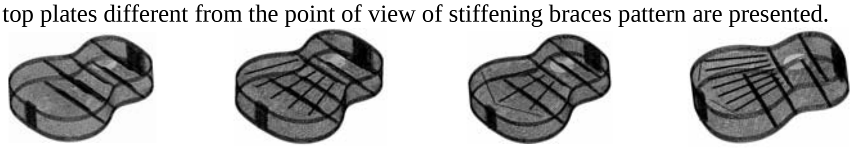
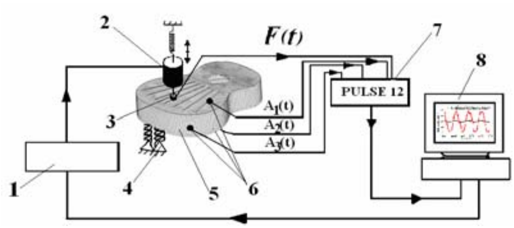


Figure1. Types of strutting system of guitar plates

2. EXPERIMENTAL SETUP
The evaluation of dynamical behaviour of guitar bodies can be done through different methods: with impact hammer or with a mini-shaker applied on structures. In this paper we will present the second method. The procedure was inspired by references namely Wright (1996) and Inta (2007) [2], [3]. The

aim of this study was to analyze the influences of stiffening braces of guitar body without neck. In previous work, the similarly studies were performed through numerical method.
The experimental method consisted of applying a harmonic excitation to the structures by means of the mini-shaker. The experimental stand was built according to the scheme in Figure 2.



1 - frequency generator, 2 - vibration mass, 3 - force transducer, 4 – spring support, 5 - sample (acoustic box), 6 – accelerometers, 7 –Pulse system B&K, 10 – personal computer

Figure 2. Block diagram representation of test

Each guitar body (5) was freely supported on a foam device (4) and excited with a B&K mini-shaker (2) located on a bridge area of the top plate. The frequencies of harmonic force: 82, 110, 146.83, 196, 246.9, 329.2 Hz (specific with the strings of guitar frequencies) and 440 Hz (la – musical note), 588 Hz (third frequency of 196 Hz) were generated through frequency generator. The input signal was measured with a force transducer (3) and the forced vibrations of each structure (the output signal) were captured with three B&K 4517-002 type accelerometers (6) (measuring on *z* direction). The recording and processing of signals in time and in frequency domain it was performed by means of B&K Pulse 12 system (7) connected to the personal computer (8). To determine the modal shapes, the top plate of guitar body was covered with a thin uniform sand layer with 100-150 grit size.

3. RESULTS AND DISCUSSION

3.1. The analyses in time and frequency domain

As it was mentioned in the first part, to record and process data the soft program of Pulse System B&K it was used. The processed signals of each measurement were displayed in numerous charts. Figures 3 and 4 presents the types of results obtained in real time.

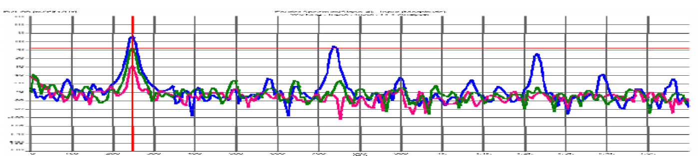


Figure 3. Energy Density Spectrum of accelerometers signals

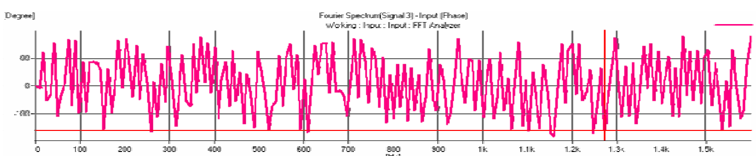


Figure 4. Phase Fourier Spectrum of accelerometer signal

In Fig. 5 is presented the variation of dynamic force with frequencies and types of guitar body. It can be noticed that each analysed structure has a different dynamical behaviour for each excitation frequency due to the influence of stiffening braces. With increasing the frequency, the differences are bigger.

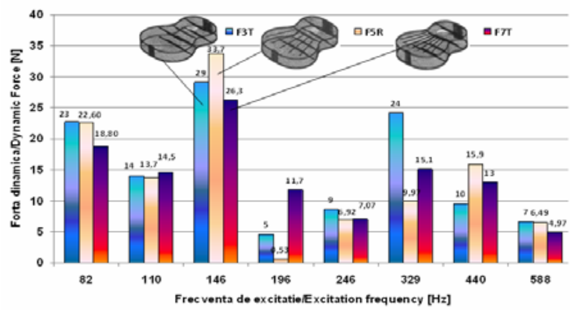


Fig. 5. Variation of dynamic force with excitation frequency and type of structure

In spite of the same values of harmonic excitation which was applied during the experiments, it was recorded different resonance frequency for acoustic bodies of classical guitar with different braces pattern. The guitar body with three transversal braces recorded the most numerous resonance frequencies. With increasing of stiffness of top plate of guitar body, the number of resonance frequency decreasing. The experimental results were compared with numerical ones as it can be seen in Figure 6. The natural frequencies and harmonics obtained through theoretical method are very closely with experimental ones, with mention that in last case were recorded more values in wide range of frequencies.

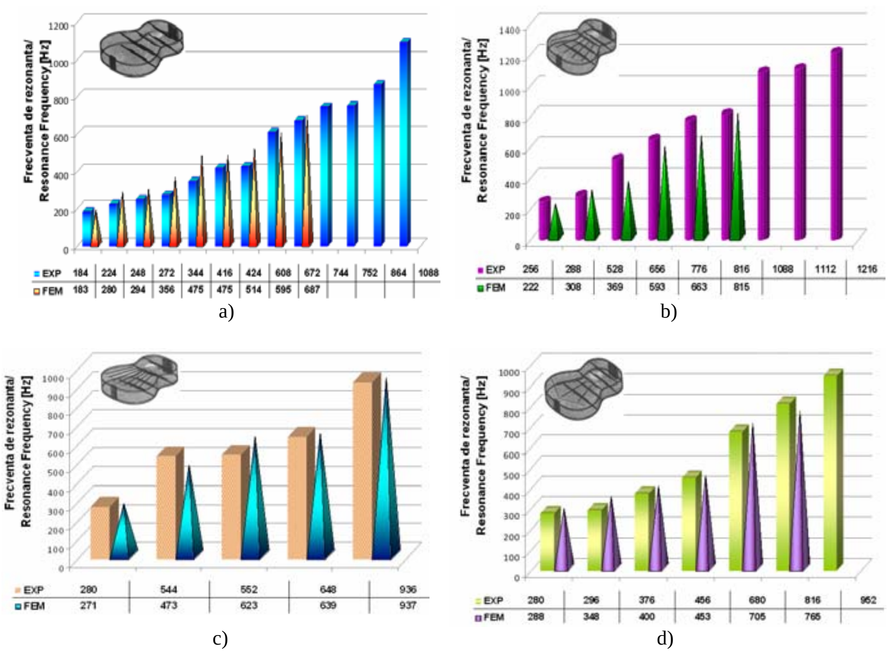
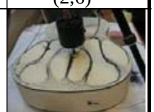


Fig. 6. Comparison between resonance frequencies obtained through experimental method (EXP) and numerical ones (FEM)

3.2. Chladni 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 (Stanciu 2009). 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 Table 1. Comparing the obtained results, it can be noticed that there are a lot of similarities regarding the modal shapes of low frequencies (110, 146, 196 Hz). With increasing of frequency, the Chladni patterns become more complex and different from a structure to another as it can be seen in Table 1. The clarity and sharply of modal shapes are obtained when the structures come into resonance with excitation force. The modal shapes are influenced by numerous factors: frequency, stiffening bars, boundary conditions, wood species.

Tabel 1. The Chladni patterns obtained in case of studied guitar bodies

	110 Hz	329 Hz	440 Hz	588 Hz	720 Hz	980 Hz
3BT	 (1,1)	 (1,2)	 (2,2)	 (1,3)	 (3,3)	 (5,3)
5BR2T	 (1,1)	 (1,3)	 (1,4)	 (1,5)	 (1,6)	 (2,8)
7BR2T	 (1,1)	 (1,3)	 (1,4)	 $(2,3)_2$	 (1,5)	 (2,6)
3BR2V	 (1,1)	 (1,2)	 (1,3)	 (1,4)	 (1,5)	 (2,6)

4. CONCLUSIONS

The experimental investigation of different types of classical guitar bodies has been performed to establish the structural differences reflected on dynamical behaviour of them. Due to the anisotropic materials from guitar structure as is wood, the results varied even the same strutting system of top plate. The approach presented in this paper is focused on structural analyses. It was neglected the influence of bridge and guitar neck. The results show that the increasing of stiffness of top plate from guitar body conduct to a structural modification visible in frequency responses of structure. The obtained data are useful for further studies which aim to optimize the guitar body taking into account the proper ratio between resistance and vibration characteristics of top plate.

5. ACKNOWLEDGMENT

This work was accomplished under the grants: PNII71-016 MODIS project manager: Prof. Dr. Grimberg Raimond, INCDFT Iasi, scientific responsible, Prof. Dr. Eng. Curtu Ioan.

6. REFERENCES

[1] Curtu I, Stanciu M, Cretu N, Rosca I, 2009. *Modal Analysis of Different Types of Classical Guitar Bodies*, in 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.

[2] Inta Ra, 2007. *The acoustics of the steel string guitar*, PhD Thesis, The University of New South Wales, Australia, September, 2007.

[3] Wright, H., 1996, The Acoustics and psychoacoustics of the guitar. PhD Thesis. University of Wales, College of Cardiff. 1996.