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RESEARCHES CONCERNING TO THE FREE AND FORCED VIBRATIONS OF THE ACOUSTIC LIGNO-CELLULOSE PLATES

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ABSTRACT

The paper presents the results of the FEM analyzing of the dynamical behavior of the ligno-cellulose plates from the guitar structures. It had been analyzed the response system in two cases: free vibrations and forced vibrations under the conditions of variation of different parameters: types of materials, density, Young's modulus, damping coefficient, thickness and structure of plates (simple and with stiffening braces). The FEM results were compared to the one's from the specialized literature in this field.

The theoretical and experimental results are useful to optimize the plate structures for improvement of the acoustic quality of the classical guitar. The paper contains manifold figures.

Keywords: FEM, free vibrations, forced vibrations, natural frequency, resonance frequency, guitar's plates

1. THE PROBLEM STATEMENT

The acoustic qualities of a mechanical structure are intrinsically linked to the material they are made of and also linked to elastically properties. The acoustical characteristics of the wooden material from the plates' structures are influenced on the one hand by the elasticity of the material along and perpendicular to the fibres, under cross and longitudinal vibrations and on the other hand it refers to the friction phenomena produced through the dissipation of vibration energy.

The resonance phenomenon is produced, which goes to the amplification of the sounds and to their emission with an improved quality of sound, of the formant harmonics produced in wood as a result of its complex and anisotropic structure. The sounds' unselectively can be obtained through complex geometrical shapes of the resonance box as it is in the case of the guitar's shape. This phenomenon is explained through the theory of division for irregular air volume contained by the box into a sum of numerous small simple volumes with a normal resonance frequency. The combination of these small volumes and their capacity of resonate offers the conditions of amplification of all the sounds emitted by the string and ideally offers the conditions of amplification evenly [5]. Depending on the period of external frequency of excitation, the resonance appears when the pulsation of the forced vibration goes near the normal frequency vibration of the wood [4]. Taking into consideration this idea it had been analyzed the dynamical behavior of the ligno-cellulose plates with different structures, thicknesses, densities and moduluses of elasticity, using PATRAN- NASTRAN 2004 package.

2. FEM ANALYSIS

The FEM is performed separately for free vibrations and forced vibrations simulation. The total number of simulations depends on the number of design variables. The output data of the dynamic analysis will be use in further optimization procedure linked with experimental validation. In the case of the undertaken researches were modelled 4 types of plates which were analysed with FEM, with shell type elements with 4 nodes as shown in Figure 1 and 2. The plates were considered being fixed edges. For establishing the influence of different factors upon the dynamic response of the plates, the following parameters had been varied: modulus of elasticity *E*, (*E= 10000, 12000, 14000 MPa*) [2], damping factor *(δ=0.02, 0.04, 0,1),* the force *(F= 1, 20 N*) applied in the nodes from the bridge area (the area where in fact it is transmitted the vibration from the strings to the acoustic plate and to the acoustic box), number of braces. There were kept constant the thickness (*h= 2.5 mm*), the density (*ρ= 450 kg/m³*), Poisson's number (*υ*=0.36) and the modulus of elasticity in shear (*G=5000 MPa).* The dynamical analysis had in view the plates' response in the case of the forced vibrations with damping at the periodical action of a concentrated unitary force which varying with the frequency 20-1000 Hz. The values of the elasticity modulus E and of the density *ρ* were taken from the specialized literature in this domain [1, 3].

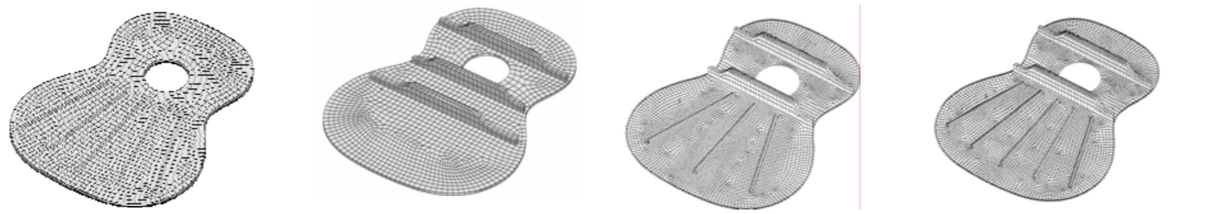


Figure 1. Numerical modeling with finite elements of the versions of considered plates [2]

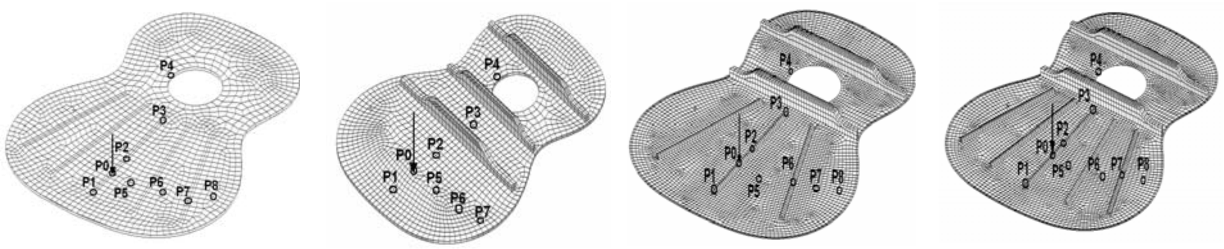


Figure 2. Distribution of the nodes established for the frequency response of considered plates

3. RESULTS

Firstly, there were analyzed the free vibrations of the lingo-cellulose plates, being obtained numerous outcomes: modal shapes of the normal modes of vibrations (Figure 3), the frequencies $f_{1...6}$ and the amplitudes' values for the first 6 modes which were analysed and summarized as diagrams.

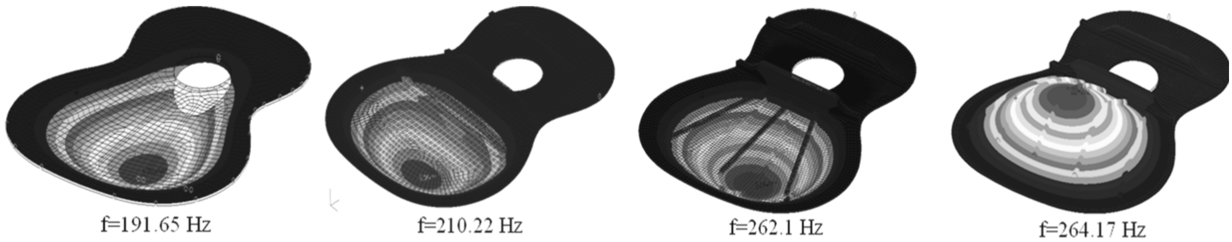
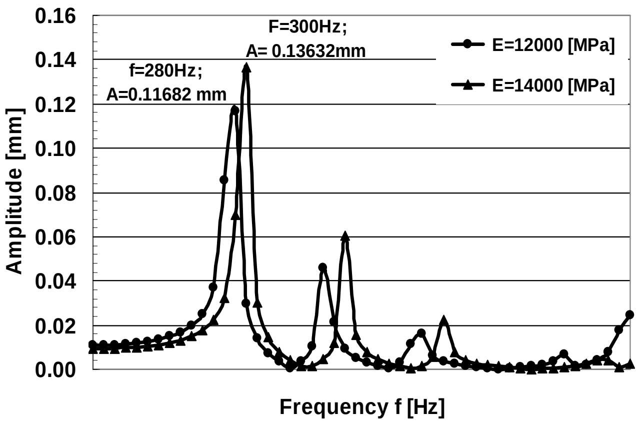


Figure 3. The modal shapes for mode (0,0) in all types of plates

Secondly, were analyzed the frequency response of the plates in the case of the forced vibrations. From the analysis of the response in the structure's nodes it can be noticed that the maximum amplitudes, regardless of the nodes' position towards the force's point of application, appear at the resonance frequency of 280 Hz for the plate with E=12000 MPa and 300 Hz for the plate with E=14000 MPa (Figure 4). For this frequency it can be noticed that the maximum amplitude is produced not in the force's point of application, according to expectation, but in the node placed near the sound hole.

The resonance phenomenon is produced also at the frequency 440 Hz and 620 Hz, but with lower amplitudes. It was analyzed the frequency response of the same nodes for the simple plate with different elasticity moduluses (*12000 MPa and 14000 MPa*), finding out that not only the amplitudes but also the resonance frequency decreased along with a decreasing of the elasticity modulus with 16%. In the case of 20 times multiplication of the unitary force it can be noticed that the frequency remains constant, but the amplitudes increase 20 times (Figure 5).



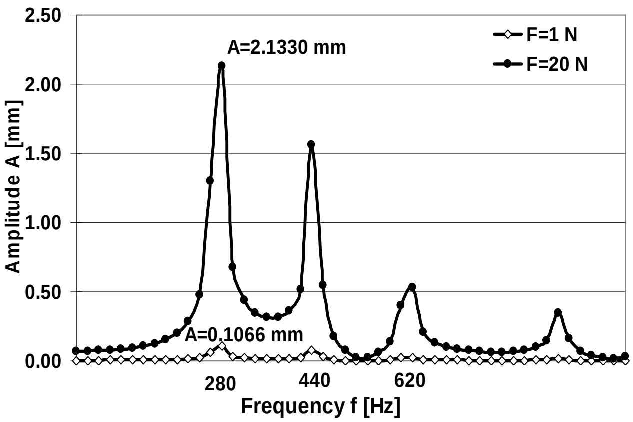


Figure 4. The amplitude variation of the node 161(P2) in the case of the simple plate

Figure 5. The amplitude variation of the node (P3), in the case of F=20 N

Another factor which influences the response of the ligno-cellulose plates under periodical vibrations is the damping factor. From the Figure 6 it can be noticed that the plates have a higher vibration damping along with the increasing of the damping factor δ. The vibrations damping for different damping factors it is made following a linear law.

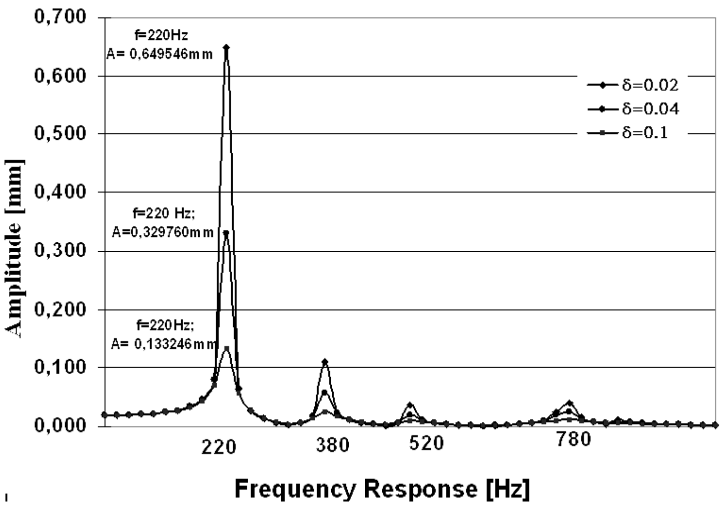


Figure 6. The amplitude variation in proportion to the damping factor

The amplitudes decrease in the modes further from the force's point of application on the cross axis of the plate, which, on the one hand, assumes that the vibration is transmitted longitudinally, being favored by the elastically characteristics and on the other hand it is necessary the assurance of a width big enough for the vibrations to radiate on a useful optimum surface. The results obtained confirm the fact that between the bridge and the sound hole it is produced the acoustic field, the area with the maximum resonance (Figure 7). For analyzing the influence of the stiffening system of the plates upon the normal frequency and the resonance one, and also the amplitudes, there was modeled simple plate, with 3 and 5 top braces plates disposed as in figure 8. The amplitudes and resonance frequency are different from the structure to another. The frequency response was analyzed and read off for the nodes placed on the symmetry axis, the nodes from around the sound hole and the nodes placed in the active area of the plate.

The modal shapes for the 3 and 5 top braces plate are similar to the ones of the simple plate obtained for low frequencies, but along with an increasing of the frequencies the modal shapes become more complex and diversified. At high frequencies the changing from one form to another it is made at short intervals of the frequencies.

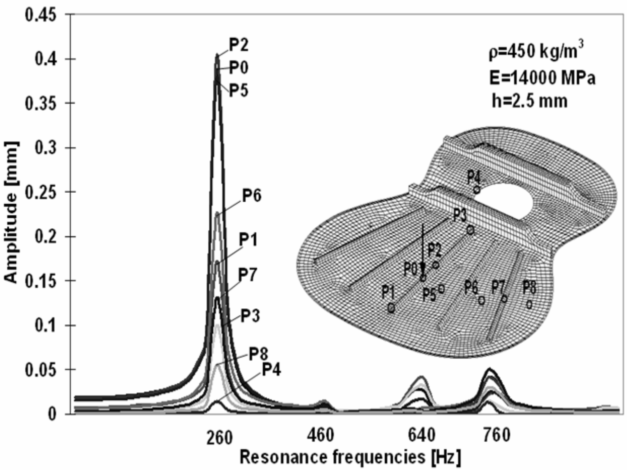


Figure 7. The distribution of amplitutes in different nodes of the plates with 5 braces

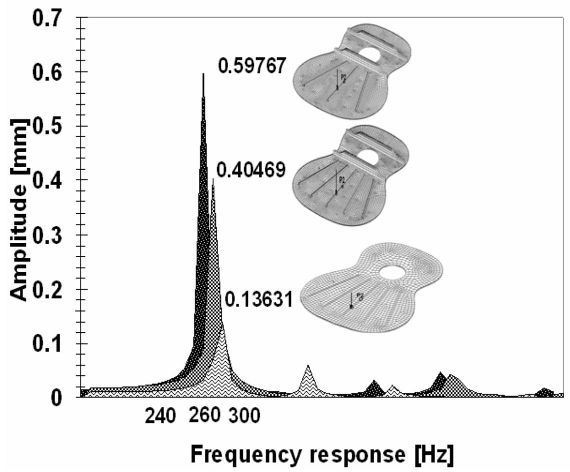


Figure 8. Comparison between the amplitudes obtained in node P2, for different type of plates

4. CONCLUSIONS

The frequency response of the ligno-cellulose plates with different structure and material characteristics offers useful information about the way in which the frequency of the excitation force overlaps with the plate's normal frequency. The modal shapes for different structure cases show the elastical behaviour of the plate, respectively the areas in which are formed the node and the amplitude loops for different vibration modes. One of the most important characteristics of the stringed instruments is the possibility of resonating at excitation frequency of the strings. On this line, the amplification box made up of the ligno-cellulose plates takes over this function, being the reason of the necessity of analysing the frequency response of the plates with FEM. The resonating domain of the plates takes shape between the bridge (the force's application point) and the sound hole. From the analysis of the dynamical behaviour of the plates it can be noticed that there are a series of factors which influence the frequency response of the plates: the plates' structure (shape, thicknesses, dimensions, back braces), the material (the wood's anisotropy, density, damping factor), the magnitude and the application point of the force.
The resonance wood and the wooden materials provide not only the plates' elasticity, but also the unselective damping of the frequencies for a range between 80-2000Hz. The dynamical analysis of the plates aimed just the structural analysis, the acoustical one being supposed to be researchd in the future.

5. AKNOWLEDGEMENT

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