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ANALYSIS OF LIGNOCELLULOSE STRUCTURES DEFORMATIONS BY QUANTITATIVE AND QUALITATIVE METHODS

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Abstract: *The paper aims to analysis the deformation which occurs in classical guitar body due to different factors such as materials – wood or lignocelluloses materials which are very sensitive to relative air humidity and temperature variations, technological process and optimal devices to fix the semi-products for processing, type of joints between subassemblies, the qualification of human operators. In this paper, the statistical results of deformation measurements and the analysis of possible causes are presented. All above factors can contribute to instability of guitar necks together with external loads from tension's strings which subject the guitar structure to bending.*
Keywords: *deformation, bending, quantitative and qualitative method, guitar*

1. INTRODUCTION

The most common defect in the guitar structure is the bend of the guitar neck. Guitar neck deformation has effects on the acoustics of the musical instrument by altering the length of the string and, implicitly, the sound / frequency emitted [1-5]. Thus, inadequate heights between strings and fretboard can manifest themselves in various aspects, such as:
- the bending (deformation) of the neck as a stand-alone structure, the body being conformed (Fig 1, b);
- the bending of the guitar face (change of the position of the shoulder towards the horizontal plane of the box), the neck remaining straight (according to) (Fig.1, c);
- loss of neck-body co planarity due to their joint defects (Fig 1, d);

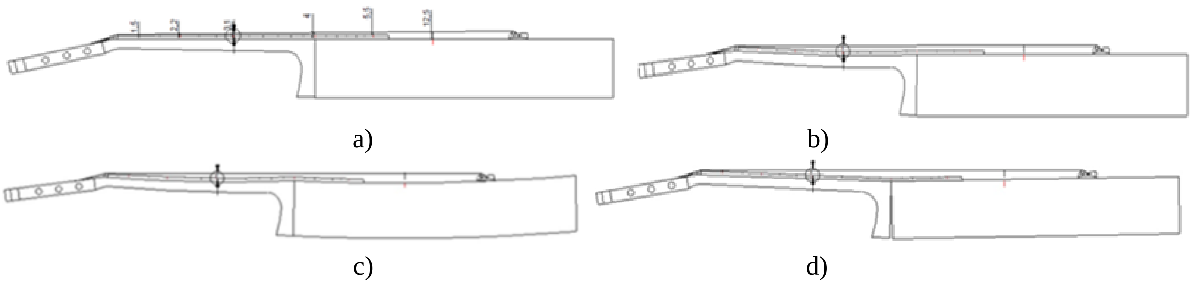


Figure 1: Types of classical guitars deformation: a) undeformed guitar; b) bending (deformation) of the neck as a stand-alone structure, the body being conformed; c) the bending of the guitar face (change of the position of the shoulder towards the horizontal plane of the box), the neck remaining straight; d) loss of neck-body co planarity due to their joint defects

The causes that can lead to these deformations are numerous and can be structured into categories: material (raw material); technological operations and working methods; equipment / work machines; human operators; work environment [6-9].

2. ANALYSIS OF ENVIRONMENTAL CONDITIONS IN PRODUCTION SECTORS

By its nature, the guitar is a wooden structure that encompasses several types of wood species with different elastic properties. Previously, the wood is dried for moisture content of 6-8%, wood-specific humidity used in the musical instrument structure. From a qualitative point of view, wood is selected in quality classes, being redeployed according to instrument class (student/school, maestro, etc.). The most common species are acacia and acacia treated with ammonia (for the fret), maple for neck, resonance spruce (face plate), hardwood plywood / hardwood for back and sides [9 – 13]. As wood is involved in guitar construction, the variation of environmental factors (humidity and temperature) leads to the swelling/shrinkage of wood following a nonlinear and irreversible law, a phenomenon called the hysteresis of swelling and shrinkage of wood. The structure of wood and its behavior over time under various loads at a certain humidity and temperature gives it the condition of elastic-plastic material. The rheological model of wood is shown in Fig. 2. For elastic-viscous-plastic materials, the characteristic curve does not express all aspects of the deformation. Studies have shown that the deformation process of wood and wood-based materials is not limited to an instantaneous shape change that occurs after the application of loads but there is a continuous process of deformation under load called creep. Thus, the distribution of stress in the guitar neck changes over time as a law of variation and position of the neutral axis, reaching the plastic stress [12-16]. Under certain conditions of humidity and temperature, under the action of the loads, which are exerted for a long time, the deformations increased.

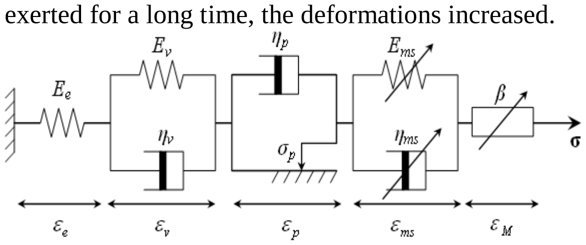


Figure 2: The rheological model of wood (http://theses.ulaval.ca/archimede/fichiers/23791/ch04.html)

Knowing that wood is a hygroscopic material, the climatic conditions (temperature and relative humidity of the air) in the production sectors are a very important factor in ensuring the dimensional stability of the semi-finished parts and assemblies (guitars as finished products) that are produced on the technological processing. At the factory, there are devices that continuously monitor these parameters, being located at control points in the plant sectors. Analyzing the average values of these parameters on the technological flow (Figures 3, a, b), we find that there is a temperature variation between sectors of 2-4 degrees C and of maximum relative humidity of 10% RH.

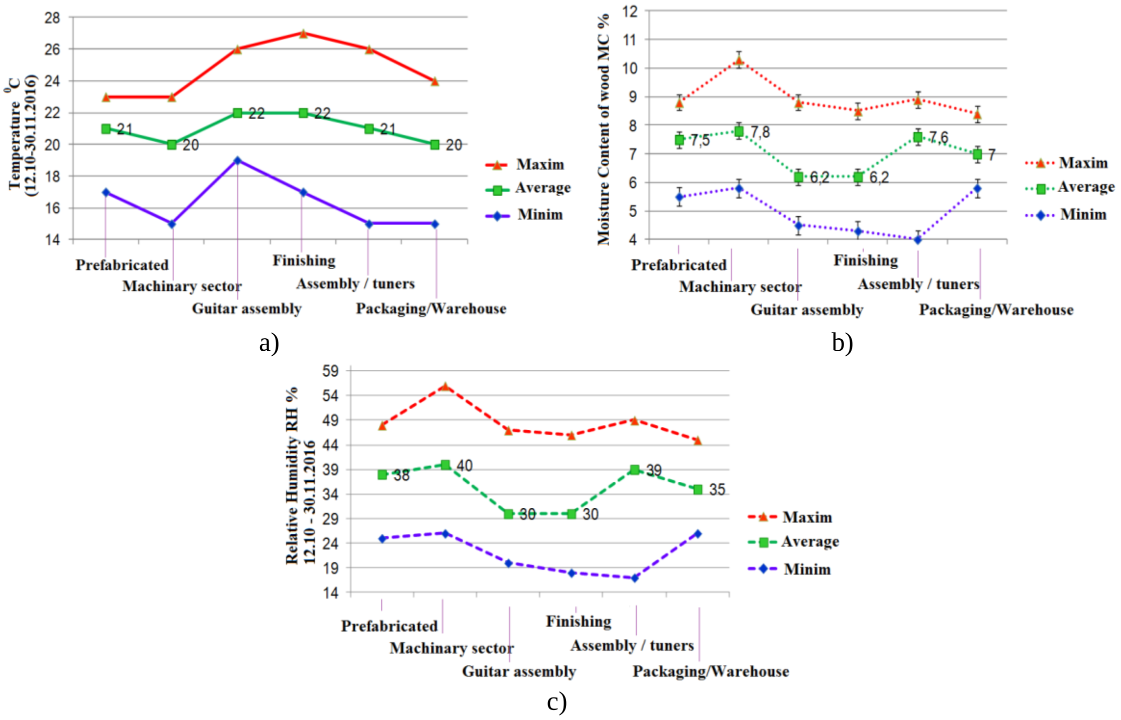


Figure 3: Variation of climatic factors in the factory sectors: a) working environment temperature; b) the relative humidity of the air, c) the theoretical humidity of the wood, during the period 12.10.2016-30.11.2016

Relative to the average values of normal conditions (T = 22 ° C, RH = 65%), it can be appreciated that the average temperature recorded in the production sectors falls within the limits of 21 ± 2 ° C, but the relative humidity of the air even in the case of maximum values, it is below the normal level (the average value is 35 ± 10%). Thus, by correlating the relative air temperature and humidity values in the Keylwerth and Noack, 1964 diagram, the theoretical humidity of the wood was theoretically determined (Fig 3, c). However, in the production sectors, the semi finished products are subjected either to technological operations involving friction between the wood and the cutting tools, thus generating heat, and thus decreasing the wood moisture, or by gluing/finishing operations involving contact with fluid state-of-the-art materials to lift the moisture in the superficial layers of wood. This subchapter deals with the variation of wood humidity in relation to climatic parameters monitored in the production sectors, without taking into account the technological parameters. Table 1 summarizes the climatic parameter values for each sector of activity.

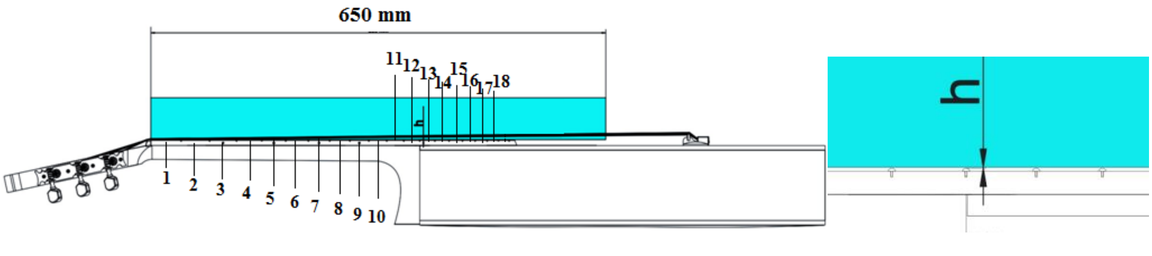
Tabelul 1. Climate parameter values monitored and calculated on the basis of the equilibrium humidity chart

The parameters	Values	Prefabricated warehouse	Machinery sector	Assemble guitars sector	Finishing	Assembly / tuners	Packaging / Warehouse
Temperature, °C	Minim	17	15	19	17	15	15
	Average	21	20	22	22	21	20
	Maxim	23	23	26	27	26	24
Relative humidity, %	Minim	25	26	20	18	17	26
	Average	38	40	30	30	39	35
	Maxim	48	56	47	46	49	45
Moisture content of wood calculated %	Minim	5,5	5,8	4,5	4,3	4	5,8
	Average	7,5	7,8	6,2	6,2	7,6	7
	Maxim	8,8	10,3	8,8	8,5	8,9	8,4

3. GUITAR'S DEFORMATION ANALYSIS BY QUALITATIVE AND QUALITATIVE METHODS

A number of geometric parameters and material (moisture content of the guitar neck structure) were quantitatively and qualitatively measured on a batch of 28 returned guitars:

• determining the distance between the frets (at each fret from 1-18) and an ideal right plane (a rigid ruler fixed on the first fret of the guitar). The distance between the ruler and the frets was measured with levers accurate to 0.01 mm (Fig. 4).



a) b)

Figure 4: The principle of measuring the heights *h*: a) the distribution of the frets; b) 12th fret detail

4. RESULTS

In Fig. 5, the flexures of the investigated guitar necks are presented. It can be seen that almost all the investigated guitars show the bent neck with the maximum flexure at the 7 and 8 frets. Also, the size of the deformations is directly dependent on the increase in the guitar weight due to the variation in the moisture content of the wood - the maximum values of the measured heights are recorded in generally for guitars with the highest weight difference. By plotting the values measured related to the standard height of the admitted height from each fret with a deviation of 0,1 mm (represented in Figure 6 with the continuous red line), there is a dispersion of the recorded values, some values being in around the admitted value. The problem is interesting because the values of the measured points have to match simultaneously with the maximum permissible error.

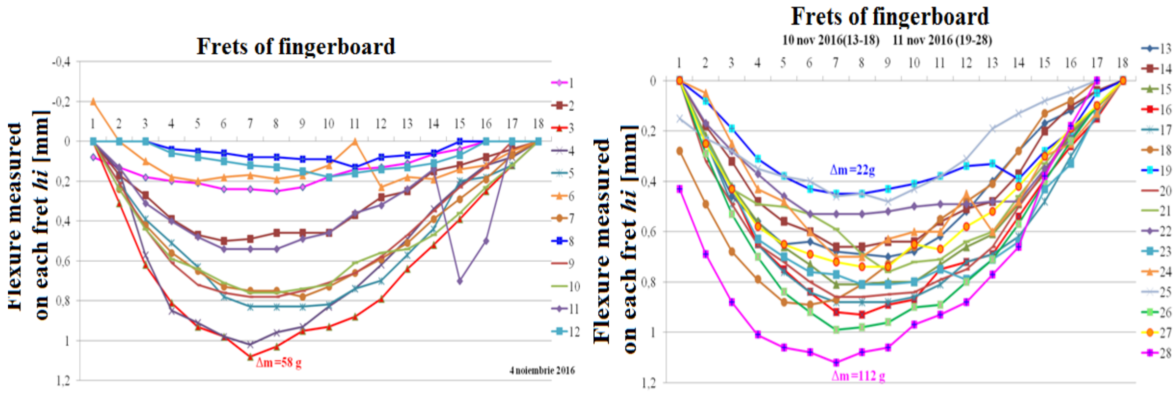


Figure 5: Variation of guitar neck deformation measured for each fret

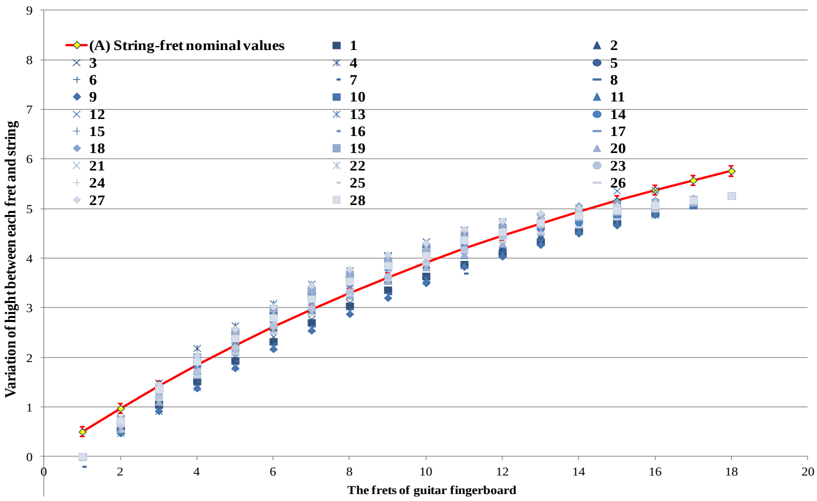
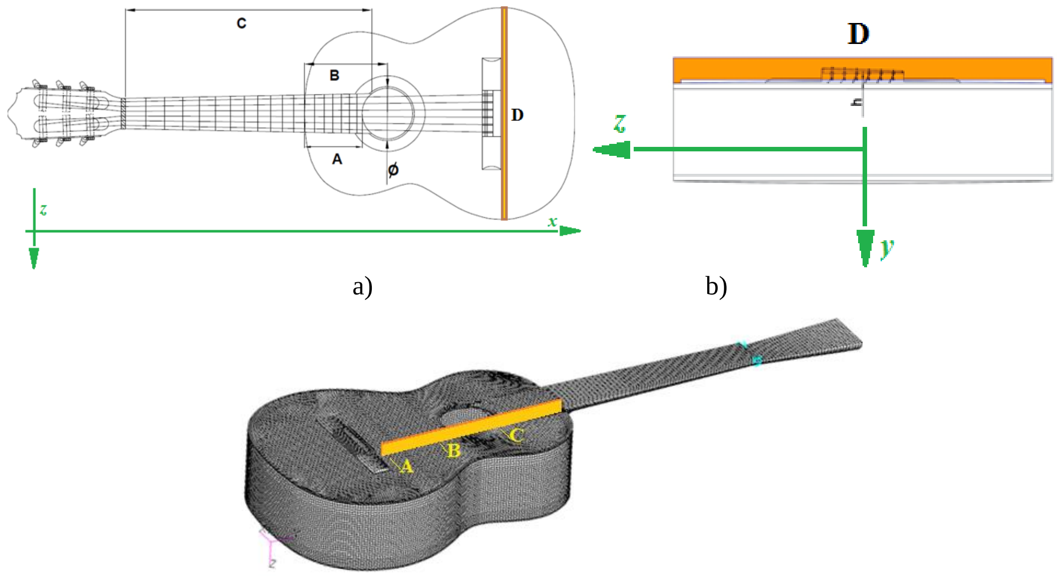


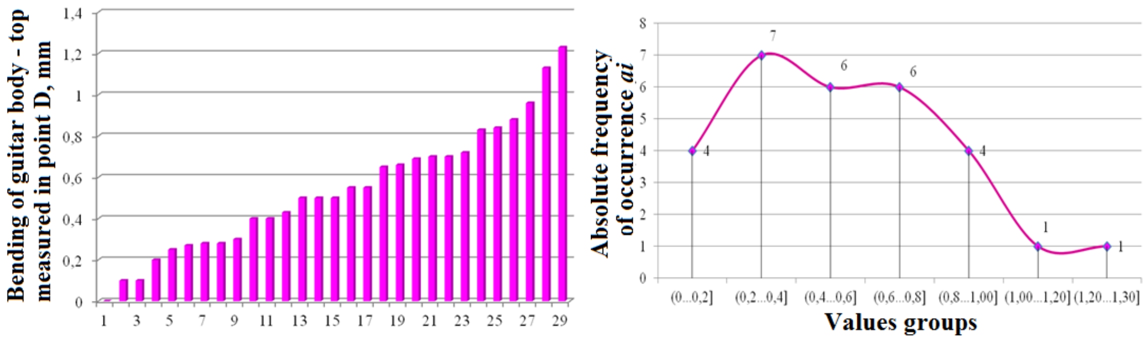
Figure 6: Deviations of the values from the nominal value of the fret-string height

In order to analyze the size of the guitar body deformations, the flatness of the guitar body was determined in the bridge area (in the yz plane), measuring the face flexure (Fig. 7).



c)

Figure 7: Diagram of the principle of measuring the flatness of the guitar face in the crotch area, in the yz direction: a) 2D upper view of the guitar; b) lateral 2D view; c) 3D view



a) b)

Figure 8: a) Increasing orderly statistics of the guitar face deviations measured in the point; b). The left asymmetric distribution of the frequency of occurrence of the bulging of the guitar face in the crown area (it is noted that the relatively small values (0.2 ... 0.8 mm) prevail)

In the xy plane the data were taken at three different points of the guitar face, according to the scheme shown in Fig. 7, c. The results revealed that the three measured points are not coplanar, recording deviations from flatness mainly in the points A and B (most of them forming a concave curvature) (Fig. 9). Table 2 shows the measured values for checking the flatness of the guitar face.

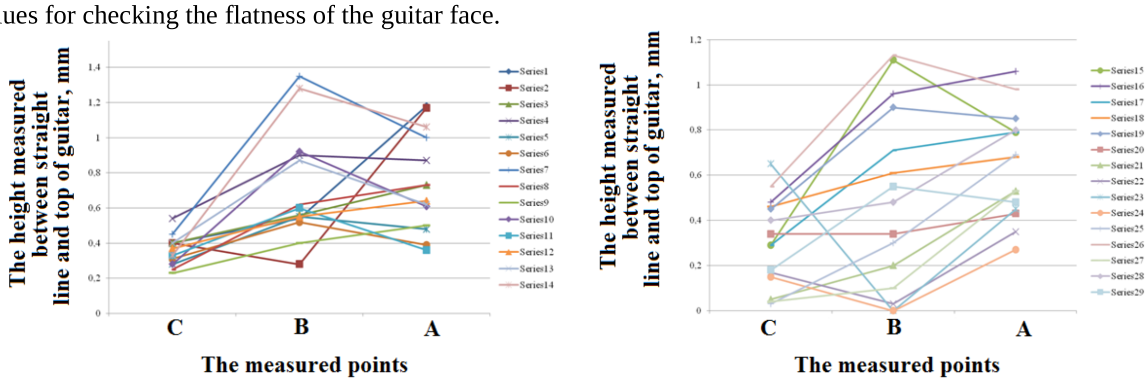


Figure 9: Variation of deviations from flatness in xy direction

Table 2: Centralize measured data to check the flatness of guitar faces

Measured points	Samples													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
D	0,28	0,00	0,83	0,28	0,65	0,70	0,96	1,23	0,27	0,70	0,88	0,84	0,69	0,66
C	0,40	0,40	0,40	0,54	0,28	0,31	0,45	0,25	0,23	0,28	0,33	0,37	0,40	0,33
B	0,54	0,28	0,56	0,90	0,55	0,52	1,35	0,62	0,40	0,92	0,60	0,55	0,87	1,28
A	1,18	1,17	0,73	0,87	0,48	0,39	1,00	0,73	0,50	0,61	0,36	0,64	0,62	1,06
Measured points	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
D	1,13	0,43	0,20	0,55	0,30	0,40	0,40	0,50	0,50	0,10	0,25	0,55	0,50	0,10
C	0,29	0,48	0,29	0,46	0,45	0,34	0,05	0,17	0,65	0,15	0,03	0,55	0,04	0,40
B	1,11	0,96	0,71	0,61	0,90	0,34	0,20	0,03	0,00	0,00	0,30	1,13	0,10	0,48
A	0,79	1,06	0,79	0,68	0,85	0,43	0,53	0,35	0,45	0,27	0,69	0,98	0,53	0,80

This is explained by the deformations that occur in the guitar face because of strings tension - in the strings area, both in the longitudinal direction (Fig. 9) and transversal, which leads to the increase of the height of the strings. The causes of these deformations may be either the high elasticity of the material or the inadequate design of the reinforcement in the bridge.

5. CONCLUSIONS

- Verifying and monitoring the dimensional stability of the parts from the neck-body-body assembly stage to the final stage (final assembly);
- monitoring the moisture content of wood at different technological stages;
- use of a dimensional compensating cordon and scissors to obtain the appropriate height between the strings and the stylus;
- Based on the analysis of climatic data on humidity and ambient temperature in different production sectors, which showed a relative humidity of approx. 40% in the factory in the cold season compared to the relative

humidity of approx. 65-70% at the beneficiary, the use of climatic humidifiers in the sectors and the monitoring of the dimensional stability of the parts were concluded;

• reinforce of guitar neck with stiffening elements;

• replacing the polyvinyl adhesive with a natural or synthetic resin without affecting the humidity of the wood to which it is applied.

• check the moisture of the two glue elements and maintain a moisture difference of max 2%.

• a good attention during the processing from human operators.

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