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RHEOLOGICAL ANALYSIS OF GUITARS SUBJECTED TO ENVIRONMENT VARIATIONS

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Abstract: *The paper presents the experimental results regarding the study of the rheological behavior of guitar necks subjected to variations of atmospheric humidity. The aim of the tests was to analyze the mechanical-sorptive phenomenon of wooden structures such as guitars. The samples were rigidly fixed in the device, thus simulating the grip of the body guitar to the neck and inserting them into the climatic chamber where the relative humidity of the air was varied. The physical measurements measured were: the moisture content of the wood in the guitar neck structure, the mass and displacement relative to the control points.*
Keywords: *rheological behavior, dimensional stability of guitars, variable environmental conditions*

1. INTRODUCTION

The structural stability of all elements in the guitar construction ensures its acoustic quality. The most common acoustic problems are due to the deformations of the neck and/ or the guitar body that occur in time. A very important factor in the visco-elastic behavior of the structure of musical instruments of wood is the moisture content of the wood, the way the wood was dried, the remaining stresses during the mechanical processing and the climatic conditions for preserving the musical instrument. Thus, wood from the structure of musical instruments is subjected to deformations due to internal tensions that develop both during wood formation (tree growth stresses) during its drying due to water movement in wood and tensions due to the technological processes to which it is subjected wood semi-finished products until the final product is obtained.

The guitar has a complex and heterogeneous geometry consisting of plates and bars of different wood species. Moreover, the way parts are mechanically processed and finished leads to different visco-elastic behavior with consequences on wood deformations. In the literature, there are numerous studies on guitar acoustics and structural factors that influence its acoustics. From the point of view of rheological behavior of wood in the guitar structure, the studies are quite poor, although one of the most common structural problems is the plastic strains of the guitar neck. This phenomenon is particularly important because the guitar structures are produced with clear specifications of the humidity content of the wood used in the structure of the musical instrument, and when they reach the storage areas of the various beneficiaries, the climate conditions are not fully respected so that, as a result of the hygroscopicity of the wood, there are defects that lead to the loss of functional ability of the guitar. This has negative economic effects, but above all effects on the environment by increasing the consumption of human, material and energy resources for repairing products or replacing them with new ones.

The study presented in this paper deals with the rheological behavior of guitar necks with different types of reinforcements subjected to humidity of air variations in the climatic chamber. The analysis was aimed at establishing deviations from the straightness of the guitar neck and the deformation velocity of samples due to the mechanical-sorptive phenomenon of wood from the structure of the guitar.

2. EXPERIMENTAL SET-UP

Samples were fixed at the same time in a very rigid steel device (a multiple stand), simulating the ideal fit between the body and the guitar neck, and were introduced into the climatic chamber being subjected to variations in humidity. In the first step, all the geometric and physical parameters of the samples were measured, namely the mass, the moisture content of the wood and the straightness of the neck compared to a calibrated straight ruler.

The samples were subjected to a T=22°C temperature in the climatic chamber, according to the test regime shown in Figure 1. Every 24 hours, the physical and geometric characteristics of the samples were verified.

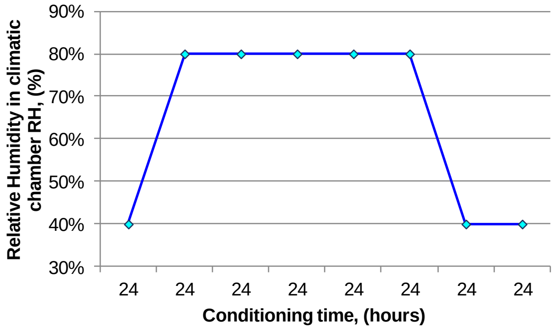

Figure 1: Testing regime in climatic chamber

From the point of view of the geometric and structural characteristics of the samples, four types of guitar necks (1) were tested, as shown in Figure 2, a. They were rigidly attached to a steel device (denoted by 1 in Figure 2, a). The sample device was inserted into the climatic chamber (Figure 2, b), and the checking of the deviations from the straightness was done with the help of a ruler type-level with the ball attached to the neck, checking with specific devices the distance between the neck and the control ruler (Figure 2, c).

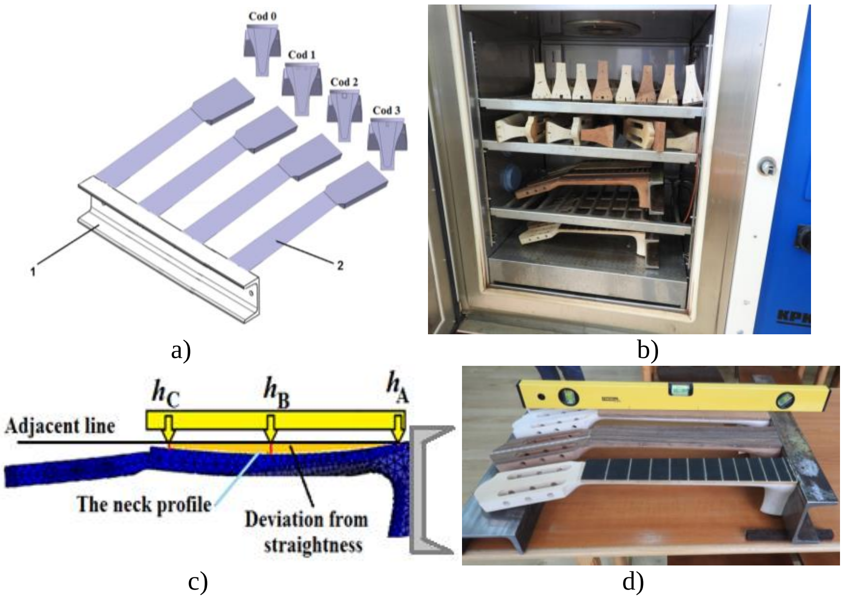

Figure 2: Experimental set-up: a) The test device (1) and the types of samples tested (2) (code 0 - single neck, not reinforced, code 1 - reinforced neck with two acacia square bars, symmetrically arranged in relation to the y-axis of the neck section; code 2 - reinforced neck with square steel pipe, code 3 - reinforced neck with rectangular steel bar (OL52)); b) climatic chamber; c) the principle of verifying the straightness deviations of the neck; d) images during the tests

Table 1 presents the physical and structural characteristics of the test samples.

Table 1: Characteristics of tested samples

Sample	Type of reinforcement	Wood species		Mass, m [g]	Moisture content MC [%]
		for fingerboard	for neck		
0.3	Without reinforcement	Sonokeling	Maple	419,97	5,0
0.4		Thermo-treated beech	Maple	379,40	6,2
0.7		Rosewood	Cedar	426,45	7,6
1.2	With two wooden bars	Black locust	Maple	380,12	5,3
2.3	With square steel pipe	Black locust	Maple	474,98	9,0
3.0	With rectangular steel bar	Black locust	Maple	448,05	7,2
3.5		Ebony	Cedar	489,20	8,6

3.8		Rosewood	Cedar	516,66	10,8

3. RESULTS AND DISCUSSIONS

Figure 3 shows the variation of the deformations graphs according to the relative air humidity in the climatic chamber. It can be noticed that there are three cases of deformations, respectively bending of the guitar neck embedded in the multiple device:

a) positive bend in which the maximum arrows are recorded in zone B (mid-sample length) - Figure 3, a, d-partial, f;

b) negative bend in which the maximum arrows are recorded in zone C (at the free end of the sample) - Figure 3, b, c, d-partial, h;

c) stable samples from the point of view of deformations (relative air humidity does not influence the straightness and flatness of the samples) Figure 3, g.

In the case of 0.4 sample (maple neck and fingerboard of thermo-treated beech) the bending is positive due to the fact that the two wood species behave differently to humidity variations: the thermos-treated beech does not absorb the same amount of water vapor (being dimensionally stable due to the thermal treatment to which it was subjected before use), compared to the maple wood which, by absorbing moisture, swells being subjected to stretching tensions (Figure 3, a).

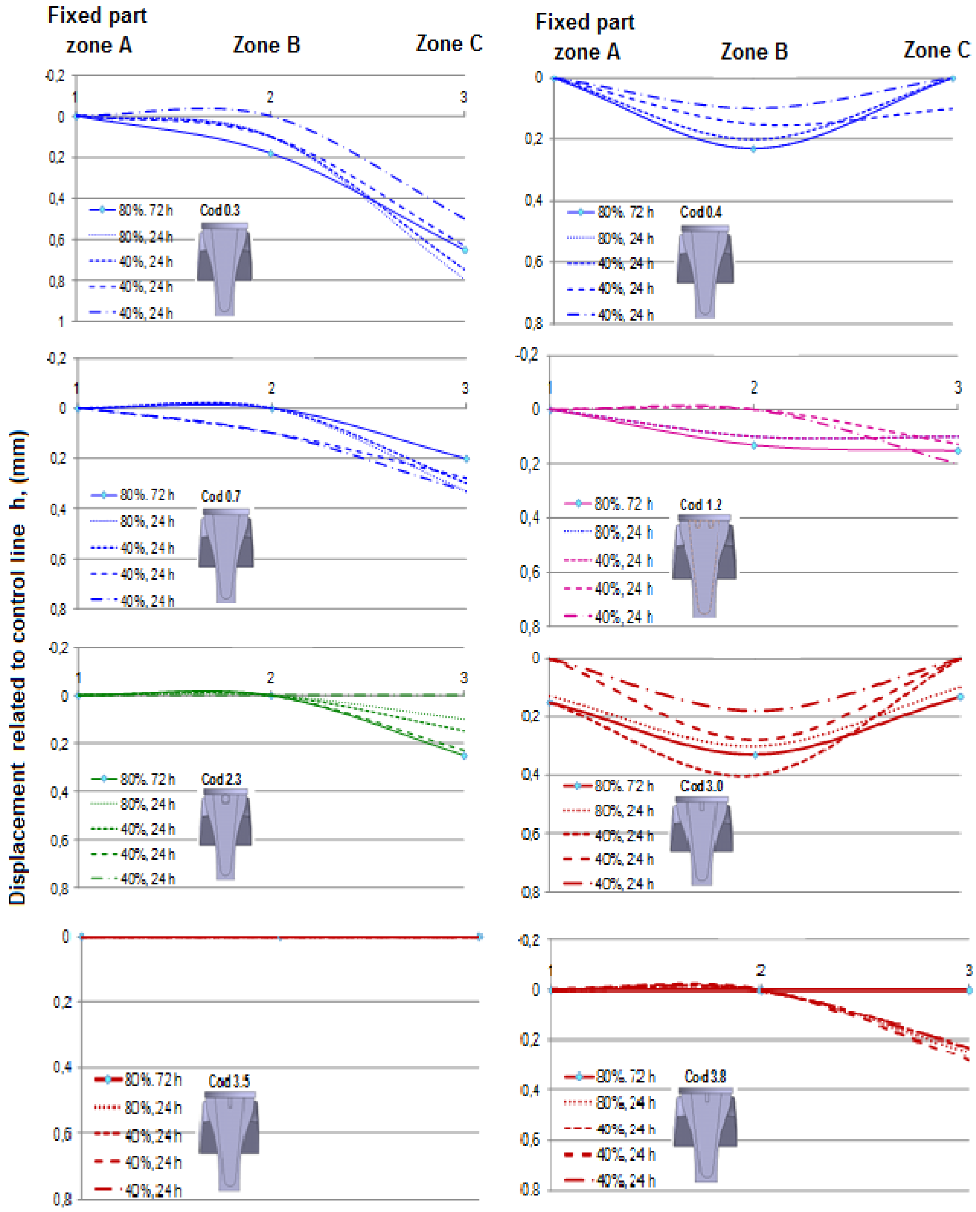

Figure 3: Influence of relative air humidity on deformations measured in the three areas of the sample

The other two samples from the not reinforced necks category shows negative bending, which implies a higher absorption of humidity by the fingerboard compared to the wood from the neck structure. Sample 0.3 contains maple wood for neck and sonokeling wood for fingerboard, and sample 0.7 contains cedar wood for neck and rosewood wood for fingerboard. Arrow values vary depending on the wood species, namely the maple with sonokeling wood is susceptible to a swelling of about 2.5 times larger than the cedar with rosewood wood (Figures 3, b and c). Exposure to a relative humidity of 40% of the reinforced sample with acacia bars (code 1.2) results in approximately 100% greater arrows than during higher humidity exposure (80%). Thus, it can be concluded that, during contraction, the evaporation of water from the wood does not occur uniformly over the whole length of the neck due to variation in the thickness (section) of the structure and due to different wood species.

Maple wood dries faster than acacia wood due to its different anatomical structure (acacia wood contains tile that obstructs the evaporation of water from the wood, leading to a delay in the drying process). It should be noted that the analysis was performed on unfinished necks, so the wood was exposed directly to atmospheric humidity variations.

In the case of reinforced sample with a square pipe, the arrows from the free end were maximum 0.2 mm in the intermediate stages of exposure, and after the last step there were no deviations from straightness/ flatness (Figure 3, e).

Samples reinforced with rectangular bar have showed different behaviors as a result of wood species combinations. Thus, sample 3.5 (cedar neck and ebony fingerboard) did not show any deviation from straightness, staying dimensionally stable irrespective of the relative air humidity value (Figure3, g). In contrast, sample 3.0, (maple with acacia) showed large dimensional variations during exposure to different humidities, as well as a positive bend. The sample of cedar with rosewood (3.8) initially straight, changed its flatness in the free end registering arrows up to 0.2 mm (Figure 3, h).

Figure 4 shows variations in the humidity content measured on the fingerboard after each exposure in the climatic chamber. From the graph shown, moisture absorption is reflected differently in the moisture content of the wood from one sample to the other.

Samples 3.5 and 3.8 are approximately stable at relative air humidity of 80% compared to the rest of samples at which prolonged exposure to 80% relative humidity results in an increase in moisture content of about 7.5% more. Decreasing of relative air humidity by 50% (from 80% to 40%) does not produce a significant decrease in moisture after 24 hours of exposure. Only after 48 hours there was a decrease of approximately 27% in samples containing maple in the neck structure and 15% in species containing cedar.

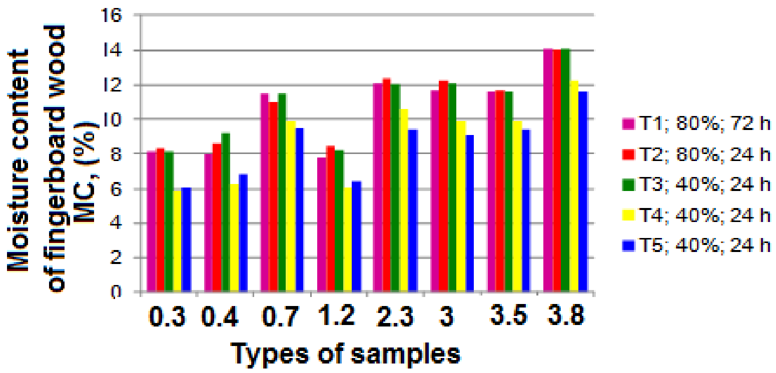

Figure 4: Variația conținutului de umiditate măsurat pe tastieră

Variation in moisture content measured on the key

4. CONCLUSION

As a result of the tests performed in the climatic chamber, the following aspects can be highlighted:

- Using some wood species with a low degree of absorption of the relative humidity of the air or a with a relative homogeneous structure can contribute to reduce the hysteresis effect manifested by different swelling and contraction behavior, such as cedar or mahogany wood (for the neck) or rosewood/ ebony for fingerboard;
- Under the conditions of use of the maple wood, it should be carefully selected so as not to present structural inhomogeneity.

- Drying of wood from the neck structure in the semi-finished stage plays an important role, therefore drying at 8-10% humidity is recommended for the neck so that it is in balance with the humidity of the air.

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