Modular guitar – the new concept of a measuring instrument

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Abstract. Musical instruments has been accompanying humans for centuries, but the knowledge about sound generation processes is still incomplete. Luthiers engaged in making classical guitars have different opinion on the influence of particular construction elements on final instrument tone and power. The aim of the project is to point the specific relations between the construction type and the sound quality of the instrument. It is of great importance both for luthiers creating classical guitars and for artists, who often seek for the instrument with very specific parameters. The main goal of the project was to design and build a special measuring instrument – the *modular guitar*, which enables to determine the influence of particular construction elements on sound thanks to the capability of combining its parts in many ways. The results of the research can considerably broaden the knowledge about classical guitar acoustics and lead to more aware design of the instruments for special purposes.

Keywords. Classical guitar, guitar construction, luthier, modular guitar

1 Introduction

The majority of classical instruments used nowadays has a centuries-old tradition. The instruments forming a classical orchestra, such as the violin family, have been appearing in their unchanged shape for decades. Comparing to them, the classical guitar is a relatively new instrument, originating from the late 18th century. The most distinctive elements of the traditional Torres construction was the circular sound hole and the fan-shaped bracing of the spruce top plate [1]. Modern luthiers often use this type of construction but the final form of the classical guitar has not been determined yet, as the instrument is still evolving. The main luthiers' motivation for such development is mostly the insufficient acoustic power of the instrument. There are different approaches of reshaping a traditional guitar body to increase its performance. Most of them concern changes in the top plate parameters – its weigh, stiffness, bracing and the shape of the sound hole. The back plate is often considered less important for the sound formation and its function comes down to transmitting the energy to the top plate. There are also some luthiers doubling the plates, adding resonant chambers to the body, experimenting with the materials etc. Although all these alterations are being introduced purposely, their effectiveness is often unpredictable. The theories about the influence of the guitar construction on its tone are mostly based on the experience and subjective impressions. To determine the actual dependencies, objective scientific research is needed. The main problem and reason why musical instruments are not properly examined lies within their nature – handmade of natural materials, even two identically looking instruments have different properties. It makes every instrument a unique piece of art, but also causes difficulties and makes the objective analysis very difficult. The way of solving the problem is introduced in the present paper in the form of a modular guitar. It is a new concept, based on constructing an instrument capable of combining its parts in many ways. Changing one parameter at the time, the determination of its influence on the acoustic quality of the instrument becomes possible.

2 Modular guitar body

The modular guitar body consists of all elements forming a classical guitar and an additional reinforced lining. It secures the instrument during the modules replacement and provides a continuous connection between the elements, as a traditional glued connection. The main asset of the modular guitar is a possibility of disconnecting both plates from ribs, due to a special notched connection between them, shown in Fig. 1, inspired by the art of Japanese wood joinery. It provides both an easy way of replacing the plates and a resonant body of a required tightness.

Fig. 1 The notched connection of ribs and plates

Another element that can be replaced is the neck, screwed to the neck block. The specific placement of the screws enables to adjust the inclination of the neck, and therefore, the string tension. The bridge and braces are mounted to the top plate with a bone glue, which is a strong connector, but releases when exposed to heat and steam.

The first built construction and the subject of present research was examined in three stages – with the raw plates of an excessive thickness, after top plate grinding to the proper thickness and after grinding the both plates. The differences in plates parameters between the stages are listed in Table 1. Other construction elements had the traditional parameters, e.g. the bracing was fan-shaped and the ribs' thickness was "3mm". All the stages were covered by one set of strings – d'Addario EJ46FF Fluorocarbon.

TABLE I: EXAMINED CONSTRUCTION PROPERTIES

		STAGE 1	**STAGE 2**	**STAGE 3**
TOP PLATE	**Weigth "g"**	173.1	164.7	164.7
	Thickness "mm" *	2.7c,e	2.5c, 1.8e	2.5c, 1.8e
BACK PLATE	**Weigth "g"**	501.9	501.9	438.6
	Thickness "mm" *	3.3c, 2.5e	3.3c, 2.5e	3.7c, 3e

* c- thickness at the centre, e – thickness at the edges

The wood species used for building the guitar are: European Spruce for the top plate, Pau Ferro for the ribs, bridge and back (with the sycamore and ebony stripes), Merbau for the neck, Gaboon Ebony for the fingerboard and Okoume for the lining.

3 Scope and purpose of the study

The presented paper discusses the general concept and the results of the first modular guitar measurement, which together with many forthcoming measurements form the project designed for broadening the knowledge about the acoustics of a classical guitar. The scope of measurement and data analysis will be extended in the future, but the main purpose of the project is to determine how different construction elements influence the acoustic power, directivity and harmonic content of the guitar. The measurements of the first parameter are performed in a reverberation chamber, using the precise method described in the ISO standard [2]. It is measured in 1/12 octave bands from "80Hz" to "10kHz". There are two approaches for the sound generation – the *scales method* and the *natural method*. The first one consists on exciting the strings one by one by an experienced guitarist with the frequency of "1Hz", up to the 10^{th} fret, and then to the last fret on the highest string. The second one assumes that the acoustic power describes the general performance of the instrument in the natural conditions – three short pieces of music covering the wide frequency range are played *attaca*, each one presenting different guitar technique and music style. All the inaccuracies caused by the natural way of sound generation are being taken into consideration and being reduced by averaging several repetitions of each measurement. The comparison of both methods is presented in the next section of this paper.

The second measurement designed for the project is completely objective. The full scale of the guitar, each note excited one by one, is recorded separately in an anechoic chamber. While one string is performing, the others are damped. Fifteen free-field G.R.A.S. 46 microphones are mounted on the "4.3m" diameter arch, spaced every "15 degrees". As shown in Fig. 2, the guitar is placed on a rotary table, turning with the step of "15 degrees".

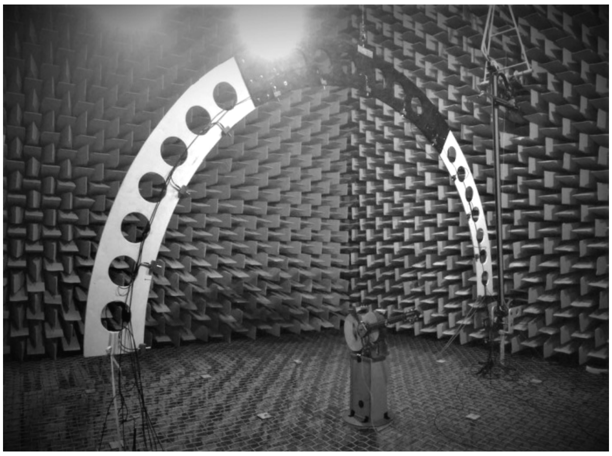

Fig. 2 The measuring set in the anechoic chamber

The main asset of this measurement is the robot guitarist, controlled from the outside of the chamber. The placement of the guitar imitates the position on the musician's leg. The guitar position on the frame and the robot are shown in Fig. 3.

Fig. 3 The robot guitarist

Recording raw guitar sounds in an anechoic environment provides data for an unimaginable scope of analyses. It can lead to the determination of each construction sound pressure levels at different notes, directivity, frequency spectra and much more.

4 Results

Both measurements mentioned in the previous section were performed on the presented guitar. This work shares only the results of the acoustic power study, since the other one is still under analysis. The comparison of the sound energy between three examined stages of the guitar body is shown in Fig. 4. and Fig. 5.

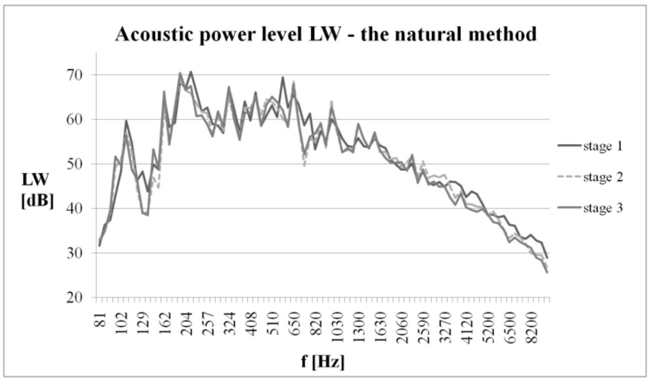

Fig. 4 Acoustic power level – the natural method

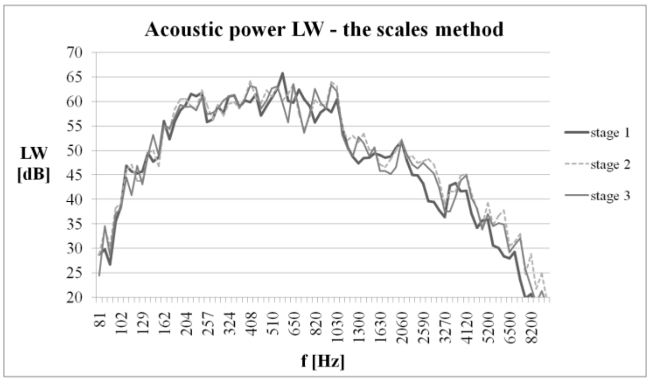

Fig. 5 Acoustic power level – the scales method

5 Conclusion

The obtained results are in line with the expectations – the alterations introduced to the guitar body were to slight to cause the considerable changes in the parameter. The differences should be more distinct in another study which is more sensitive to details. For this first measurement, most important than the information about the guitar itself was the verification of the applied methodology. The results show that the scales method gives more reliable results – the curves are smoother, while the natural method enhances visibly some frequencies. The only conclusion from this stage of research can be that the thickness of the plates affects mostly the frequencies above "1kHz" – differences in lower frequencies seem to be negligible. Further works will include improvements of the methodology, e.g. more repetitions of the measurement for averaging, to obtain more accurate results. Summing up, the whole project requires a lot of time and is still in the stage of design, but it can contributes significantly to the general knowledge about the classical guitar, leading to better understanding of its complex acoustics.

Acknowledgments

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References

[1] Thomas D. Rossing, *The Science of String Instruments*, Springer Science+Business Media LLC, pp. 20, New York 2010

[2] ISO 3741:2010 *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Precision methods for reverberation test rooms*