Effect of the Ebony Crown on the Higher Register of the Classical Guitar

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The luthiers expertise developed over the years by André BRUNET, Master Luthier and Director of the Bruand Lutherie School led him to ask Jean-François JARRY to run experiments. Those experiments are design to qualify and quantify the effect of the alteration Mr. BRUNET has integrated in his Guitar designs over the years. Varying the material of a crown on the head of the classical guitar is one of the latest experiments run at the Lutherie School. The head of a guitar was altered in order to be fitted with crowns and two crowns with the exact same geometry were manufactured, respectively in Mahogany and in Ebony. The Mahogany crown matches the Mahogany neck of the Guitar used for this experiment. Through the recording of a great number of notes and their analysis using the Praat software, the effect of the Ebony crown has been enlightened: Especially for the higher register of the guitar, the timbre is enhanced in its proportional higher frequency components..

1 Introduction

Bruand Lutherie School started making research at the early beginnings of its existence. The school's director André Brunet has a natural inclination for practical research and hired Jean-François Jarry with 2 goals: 1) lead the research program they build together and 2) allow the students to run their own experiments and help them continue to research through their everyday practice. This paper relays the methodology and results of one of the last experiment run by Jarry and Brunet at the Bruand Lutherie School. Because they run no university research , the lack of people and funding led them to develop their own methodology and research protocol. Therefore, the following methodology might seem to be slightly less rigorous than usual academic work and it might indeed be less rigorous. This paper doesn't aim to become a reference. It aims to relays the results Jarry and Brunet get and to create a discussion to improve further research at Bruand Lutherie School.

2 Methodology

First, we will describe what the experiment consist of and how the samples are decomposed. After that we will explain the analysis process of the data that lead to the results of this paper and finally we will have a few words on the overall recoding conditions.

2.1 Impulsion creation

The main problem encountered by Jarry and Brunet was the impulsion creation. In order to get a pretty good repetition of the impulsion, they should have freed themselves from the human interpretative variable. They developed a "robot" in order to achieve this goal. It is a simple stand, fitted with a pick, linked to a machined serrated wheel. By turning the wheel, the contact point of the stick holding the pluck is raised until it reaches the step and the pick plucks the string. Still, these operations must be performed by hand but the variation of the energy transmitted to the string is highly reduced. This manual robot stabilises as well the variation in plucking position. Since it is linked to the stand, once the plucking position of the robot is set, a good stability is achieved.

2.2 Sample decomposition

With the impulsion stabilized, the sample remained non consistent in their spectrum as well as in their duration. In order to compare them anyway, Jarry developed the following double sample decomposition: temporal and spectral.

2.2.1 Temporal decomposition

Even if the temporal variation was reduced through the use of a robot, the samples were divided into 15 time periods. The 2 first time periods (P1 and P2) have fixed time length of 0,1s. P3 to P9 have the same duration, proportionally to the overall length of the sample. Each of these time periods lasts 1/18 of the sample length. P10 to P14 also have proportional length, only this time they last 1/9 of the total sample length. The last period P15 starts after P14 and lasts the remaining time.

This temporal division was chosen in order to have the two first time period with comparable time length, and the remaining periods comparable in proportion, whatever the sample length.

2.2.2 Spectral decomposition

The same reasoning was applied in the frequency domain. A strategy was needed to be able to compare meaningful frequency ranges. Again, the used decomposition is home developed. The audible frequency range is decomposed into six frequency ranges. The Table 1 shows the various frequency domains.

Splitting the frequency domain with this model is supposed to allow a correct comparison between notes of the same pitch (if an effect of the timbre is researched) or on notes of different pitch. This grid has mostly been developed empirically; so its complete relevance should lead to further investigations.

Table 1 : Spectral decomposition model

Name	Min	Max
Masse [Mass]	20Hz	450Hz
Coeur [Heart]	450Hz	2,6 KHz
Identité [Identity]	2,6 KHz	4 KHz
Personnalité [Personality]	4 KHz	7 KHz
Proximité [Proximity]	7 KHz	10 KHz
Brillance [Brightness]	10 KHz	20 KHz

2.3 Data analysis

The data has been treated using the numerical sequencer of the software Logic. Once the frequency decomposition has been made through Logic, the Praat software was used to analyze the samples and the filtered samples.

The main thing was to compare the intensity levels (in dB) or the energy (in J) of the various time periods or frequency periods.

To do that the following tools were accessible: A sound level meter was set up just near of the microphone during the recording of the samples. 4 other level indicators have been used: the internal numerical sound level meter at the input of the sequencer of Logic Pro and the 3 level and energy indicators of Praat (the Max indicator in dB SPL from the 'Intensity'-menu; the Max View indicator in dB SPL from the 'View'-window; the Joule value). For one note in particular, the various indicators showed only small variation. This variations lead to computed differences. Over the reference set of samples, the maximum differences have been compiled in the Table 2.

Table 2 : Comparison of the level indicators

Level indicator	Max. difference [dB]
Sound Level Meter	0,120
Logic	0,001
Max	0,003
Max View	0,018
Joule	0,008

Because of the overall consistency of these indicators and the very few variations of the indicators of the Praat software, only Praat was used as a reference in the data analysis.

2.4 Recording conditions

The recording of the sample has been performed in a quiet recording room. As no anechoic room was accessible to Jarry at this point the sample were recorded in the best possible conditions. At least all the samples have been recorded in the same room in 2 sessions of 4 hours on two consecutive days.

A Brüel and Kjaer 4011R microphone was used to record the samples in mono, at 44 KHz in 24 bits. The microphone was positioned in front of the guitar on the first day. Neither the guitar, nor the stand, nor the microphone has been moved until the end of the samples recording.

2.5 Specification of guitar and crowns

The guitar used in these experiments is a classical Godin guitar. The neck is made of mahogany. A mortise and tenon joint is used to assemble the crowns on the neck. On the neck half an inch (1,27cm) of mahogany has been removed to create the tenon.

The crowns have the same dimension. They are dimensioned to fit the neck as mortise. Two crowns have been developed for this experiment:

- One crown in mahogany. The material comes from another classical guitar of Godin. The same model from the same production series. The grain of the wood is very similar to the grain of the guitar, and in the same direction. Also the densities are really close.
- One crown in ebony. This time, the density is not comparable. The density of this ebony piece is around 1050kg.m^{-3} and the grain is set up in the transversal direction to the grain of the mahogany of the guitar.

3 Samples description

The samples have been taken for various notes on the guitar. They all come from the '1st' string, the highest Mi-string. The recorded notes are the following:

Ré ♭ $_5$ 9th fret , Ré$_5$ 10th fret, Mi ♭ $_5$ 11th fret, Mi$_5$ 12th fret, Fa$_5$ 13th fret, Sol ♭ $_5$ 14th fret, Sol$_5$ 15th fret, La ♭ $_5$ 16th fret, La$_5$ 17th fret, Si ♭ $_5$ 18th fret and Si$_5$ 19th fret.

Two set of samples have been recorded. The first set is the reference set. Only the mahogany

crown has been used. The other set of sample come from the guitar with the mahogany crown and with the ebony crown.

4 Results

The reference set of sample was as described in the Figure 1. So, in average 10 samples are used for the reference series A and of 10.1 for the reference series B.

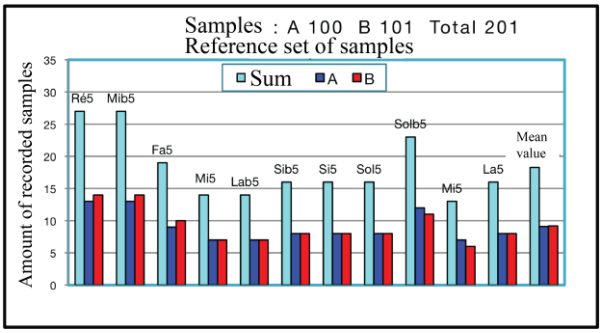

Figure 1 : Reference set of sample description

The set comparing the mahogany and the ebony crown is described in the Figure 2. An average number of 20 samples have been recorded with the mahogany crown and 21 samples with the Ebony crown for all the notes.

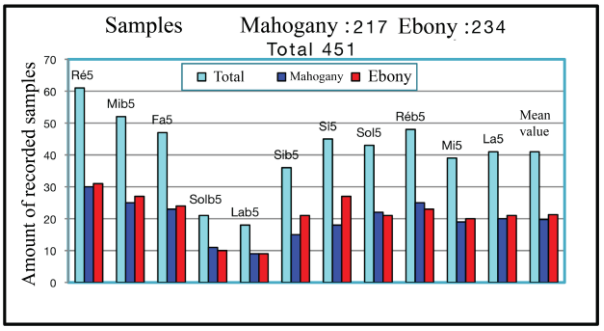

Figure 2 : Number of samples regarding the crown's nature

One of the clearest effects of the crown was on the time duration of the samples. The Table 3 shows the average variation between the series A and B setting the reference.

The comparison between the ebony and the mahogany crowns show the impact of the ebony crown on sustain of the played notes of the guitar. With an average difference of 0,058s (around 1.7%) the plucked notes with the Ebony crowns lasts longer as show the Table 4.

Table 3: Time comparison of the reference samples

	A Series	B Series	A-B
Notes	[s]	[s]	[s]
Ré5	3,990	3,997	-0,007
Mib5	3,990	3,997	-0,007
Fa5	2,763	2,765	-0,003
Solb5	3,039	3,027	0,012
Lab5	2,787	2,753	0,034
Sib5	2,168	2,179	-0,011
Si5	1,840	1,863	-0,022
Sol5	3,666	3,653	0,013
Réb5	5,213	5,156	0,057
Mi5	3,943	3,996	-0,053
La5	3,366	3,354	0,012
Average	3,342	3,340	0,002

The comparison between the ebony and the mahogany crowns show the impact of the ebony crown on sustain of the played notes of the guitar. With an average difference of 0,058s (around 1.7%) the plucked notes with the Ebony crowns lasts longer as show the Table 4.

Table 4 : Time comparison of samples with Ebony crowns and Mahogany crowns.

	Mahogany	Ebony	Diff.
Notes	[s]	[s]	[s]
Ré5	3,987	4,085	-0,099
Mib5	4,245	4,196	0,049
Fa5	2,744	2,895	-0,151
Solb5	3,018	3,147	-0,129
Lab5	2,744	2,750	-0,007
Sib5	2,179	2,255	-0,076
Si5	1,851	1,903	-0,052
Sol5	3,648	3,730	-0,082
Réb5	5,187	5,156	0,031
Mi5	3,975	4,048	-0,073
La5	3,344	3,399	-0,055
Average	3,357	3,415	-0,058

The other clear result that these experiments produce is the impact of the ebony crown on the timbre. The two following figures show the level variation between the two series of reference sample and between the two crowns. It only considers the first time period (P1) and decomposes it following the frequency grid that was previously described.

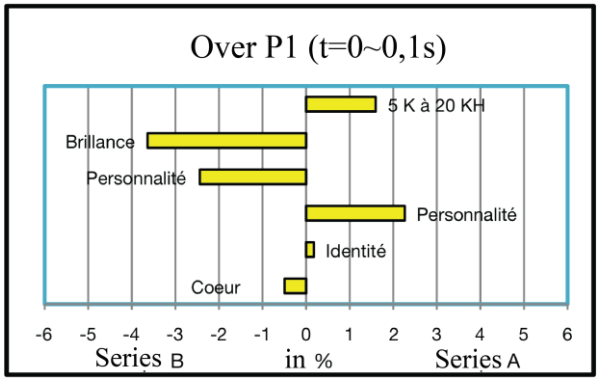

Figure 3 : Comparison of the timbre over P1 for the reference samples

Figure 3 shows the variation in intensity level for the 5 main frequency domains. We can notice that there is only small differences (max 4%), and no clear trend between the series A and B.
Figure 4 shows the same variation. Only, this time, the Ebony crown shows a massive difference with the Mahogany crown, especially in the higher register (near of 20%). Only the Coeur [Heart] has a higher level for the Mahogany crown.

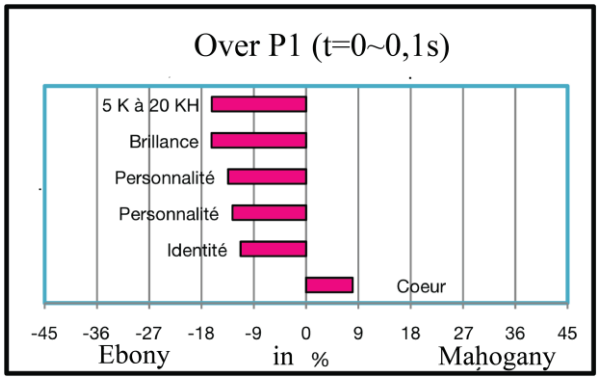

Figure 4 : Comparison of the timbre over P1 for 2 crowns

5 Conclusion and perspective

Following the empirical knowledge of Brunet, the experiments run by Jarry show the clear impact of the mahogany crown on the timbre of the higher register of the classical guitar. There is more energy in the higher frequency ranges and the plucked notes lasts a bit longer. The experiment showed a trend but this trend was not seen for all the notes of the samples.

Since February, collaboration has been created between the CIRMMT, Bruand Lutherie School and the University of Montreal. The first act of this collaboration will be a continuation of this study using the CIRMMT facilities. An impedance measurement of the guitar with various crowns will be performed in a first time in order to have another comparison source for those results.

Acknowledgments

We would like to thank Caroline Traube and Gary Scavone for their support. We also would like to thank ISMA for accepting us. This paper comes from a really young collaboration and the lack of scientific references for the methodology or for the concepts will be improved in a near future.