DOI: 10.61782/fa.2023.0712

forumacusticum 2023

VIBROACOUSTIC DESCRIPTORS OF CENTRAL AFRICA HARPS

François Fabre[1*] **Jean-Loïc Le Carrou**[1] **Baptiste Chomette**[2]
Sylvie Le Bomin[3]
[1] Sorbonne Université CNRS Institut Jean Le Rond d'Alembert
Equipe Lutheries-Acoustique-Musique F-75005 Paris, France
[2] Univ Lyon, Ecole Centrale de Lyon, CNRS, ENTPE, LTDS, UMR5513, 69130 Ecully, France
[3] Institut de Recherche en Musicologie, Quai François Mauriac, 75706 Paris, France

ABSTRACT

Central Africa harps are string instruments, often anthropomorphic, whose soundbox is built from a hollowed out tree trunk. They contain a set of strings (usually between 5 and 11) which are bound to wooden tuning pegs on the neck and attached to a tailpiece placed under the soundboard. The constitutive material of each instrument-making element may vary according to ethnic groups and material availability which induces acoustic differences. The present study deals with the definition of relevant vibroacoustic descriptors in order to assess the specificities of a Central Africa harp. Experimental data, collected on specimens from several ethnic groups, allow to test frequency domain descriptors already discussed in the literature for other musical instruments.

Keywords: *harp, central africa, vibroacoustics, descriptors*

1. INTRODUCTION

Harps from Central Africa play an essential role in social activities such as initiation rites and therapeutic practices [1]. They usually are at the center of musical pieces with an important symbolic representation. The different ethnic groups reveal a great diversity of harps in terms of repertoires, designations, morphological and acoustic characteristics. In the frame of an interdisciplinary research project (Ngombi) aiming at determining the evolutionary mechanisms of these instruments, vibro-acoustic descriptors (destined to be collected on-site) are looked for.

The present study, which follows on a previous paper [2], focuses on 6 gabonese harps at our disposal (coming from 5 different ethnic groups) and is about testing frequency domain vibro-acoustic descriptors already proposed in the literature on other musical instruments such as guitars [3] or concert harps [4].

A brief presentation of the harps studied in this paper is given in section 2. Then section 3 presents the experimental setup used to collect data. Experimental results regarding the vibratory descriptors investigated are then analyzed in section 4, giving rise to prospects for future works.

2. CORPUS OF HARPS

The 6 harps included in this paper (see Fig. 1) represent 5 ethnic groups: Eshira, Fang, Massango, Nkomi and Tsogho. They all have a soundbox made of a hollowed out tree trunk on which a soundboard made of animal skin is stretched and nailed. Their soundboard is made of a single piece except for the 2nd Fang harp and the Tsogho harp. A principal opening is present at the bottom of all soundboard and the two Fang harps also show multiple smaller holes near the top. They all contain 8 strings in fishing line of gauge ranging from 0.8 mm to 1.1 mm. These strings are coupled to the soundboard through a tailpiece placed under it and are wrapped around the neck and wooden pegs crossing it, thus allowing for their tuning. Finally, the neck is fitted on top of the soundbox and bound to it

*Corresponding author: francois.fabre@sorbonne-universite.fr.

using a metallic wire or plant-based material going trough two previously drilled holes.

Figure 1: Corpus of harps investigated

In the following, the strings are numbered from 1 to 8, 1 being the longest (lowest pitch) and 8 the shortest (highest pitch). It should be noted that only the relative tuning between strings is pertinent, harpists may adjust the absolute tuning to obtain a desired tension or to facilitate the acoustic radiation. Independently of the ethnic group, strings 7 and 8 are tuned at the octave of strings 1 and 2.

3. EXPERIMENTAL SETUP

In order to compute the descriptors presented in section 4, experimental data are collected following the experimental setup shown in Fig. 2. Hanging the harps using bungee cords allow to approximate free boundary conditions during the measurement. The static string/body coupling is kept but a strip of felt is intertwined with the strings to dampen their transverse vibrations and avoid a dynamic coupling. The strings are tuned as close as possible to their original tuning. The vibratory behavior of the body is obtained through frequency response functions (FRF) measured using a roving automatic impact hammer (force sensor PCB 086E80) and four reference accelerometers (PCB M352C65) placed at the coupling point of string n°3 with the neck (in two transverse polarisations), at the coupling point of string n°3 with the tailpiece and in the middle of the back of the soundbox as shown in Fig. 2. A fifth accelerometer (PCB 352C23) is moved alongside the impact hammer to measure collocated FRFs at each string attachment point.

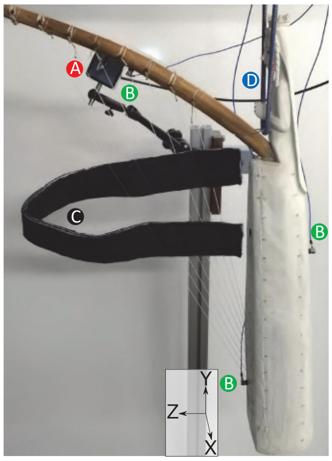

Figure 2: Experimental setup. Ⓐ: automatic impact hammer, Ⓑ: accelerometers, Ⓒ: strip of felt, Ⓓ: bungee cord

4. DESCRIPTORS

4.1 Conductance map

The representation of collocated conductances (real part of the mobility) along string attachment points is an efficient tool to report on the spatial and frequency evolution of the soundboard response in the low frequency range. The superposition of strings' partials, in combination with the knowledge of the modal basis of the soundboard, allows for a quick interpretation of potential string/soundboard and string/string couplings. A conductance map for each harp of the corpus is shown in Fig. 3 with white arrows linking some conductance peaks with the corresponding mode shapes presented in Fig. 4. It should be noted that the original tuning of the Eshira and Nkomi harps are not known by the authors, however potential tuning ranges can be estimated from the gauge and length of the strings following the work of Woodhouse [5]. These are represented in Figs. 3f and 3e by horizontal lines of different shades of gray linked to the partial orders.

From Fig. 3, it clearly appears that the Massango harp has an overall higher conductance, followed by the Eshira harp, which indicates that energy transfers between the strings and the soundboard will be more pronounced

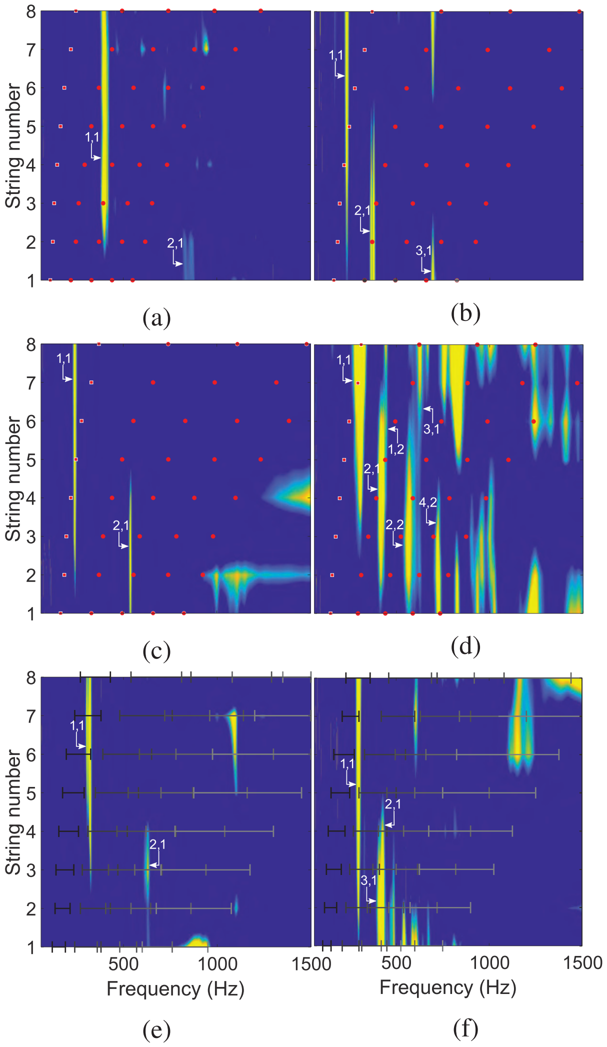

Figure 3: Conductance maps. Each plot shows a range of 7 dB. Red squares: fundamental string partials. Red circles: higher order partials. Grey shaded horizontal lines: potential tunings of the Nkomi and Eshira harps. (a) Tsogho, (b) Fang, (c) Fang2, (d) Massango, (e) Nkomi and (f) Eshira

for those harps thus increasing the acoustic radiation at the cost of a shorter decay time. When looking at Figs. 3a, 3b, 3c and 3e, one sees that, for all harps, modes 1,1 and 2,1 exhibit the highest response, followed by the mode 3,1. The spatial spread of string attachment points may thus strongly influence the potential for sympathetic vibrations between strings. Finally, the frequency of the first bending mode (1,1) doesn't coincide with any fundamental string partial of the Tsogho harp while it coincides with the one of the fourth and fifth strings of the Fang harps and the seventh and eighth strings of the Eshira, Massango and Nkomi harps. This further explains timbre variations between all these harps.

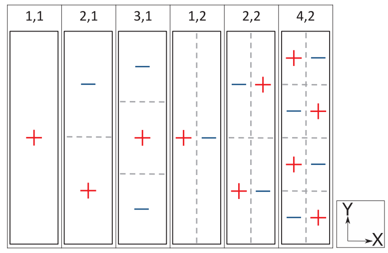

Figure 4: Modeshapes of the soundboard

4.2 Mean Value of Mobility

Analyzing separate modal contributions in the low to medium frequency ranges gives useful insight on the vibratory behavior of the harps. However, once these contributions overlap in such a way that it becomes impossible to discriminate them, a global analysis becomes more relevant. One descriptor proposed in the literature [6] to summarize the response of a structure in the medium to high frequency ranges is called the Mean Value of the Mobility (MVM) and simply consists in averaging the mobility level in dB over a given frequency band. Fig. 5 presents the evolution of the MVM over string attachment points for all harps of the corpus. The frequency range used to compute these MVM starts at 500 Hz, since the modal overlap factor is around 30 %, and is limited to 2000 Hz due to the hammer force.

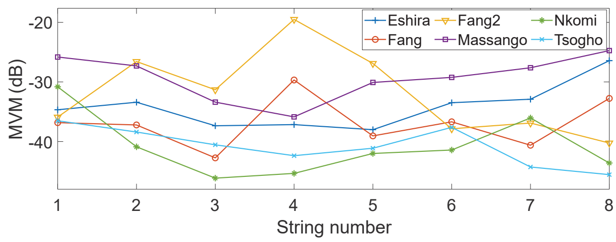

Figure 5: Mean Value of collocated Mobilities on the tailpiece of all the harps

It is worth noting that the two Fang harps show similar trends of the MVM with important variations between adjacent strings which may introduce an inhomogeneity of the instruments. It would be interesting to further investigate this on a wider sampling of Fang harps. The second Fang harp has the highest MVM of all the corpus with -19.5 dB at the fourth string, followed by its second string (which is in agreement with Fig. 3c). Apart from this harp, the higher global mobility of the Massango, followed by the Eshira harp, is recovered with respect to conductance maps. The MVM of the Eshira, Massango and Tsogho harps are the most uniform despite having different spatially spread string attachment points.

When conducting the experimental modal analysis of the harps, a non-negligible influence of the air humidity on the modal frequencies of the harps was observed (leading to wrongly identified poles' multiplicity). In order to investigate the robustness of the MVM with respect to these changes in air humidity, the soundboard mobility of the second Fang harp is measured at different instants. The results are displayed in Fig. 6 for an air humidity ranging from 36 % to 46 %.

Despite important shifts in resonance frequencies (for example a deviation of approximately 7.5 % at 400 Hz for the mode 2,1) the global trend of the mobility remains stable, except for a pronounced drop in modulus around 1.4 kHz for an air humidity of 46 %. This is confirmed by the five MVMs which show a maximum difference of only 1.8 dB. This tends to indicate that the MVM is a robust descriptor in view of on-site measurement. In light of this result, further investigation is to be conducted on a longer period of time, a wider range of air humidity and several harps.

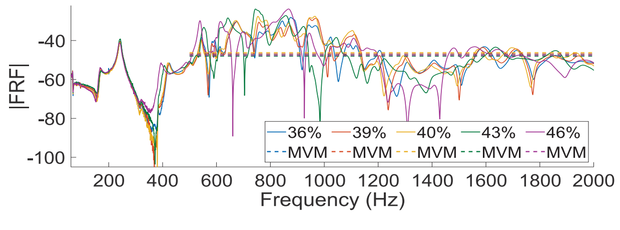

Figure 6: Soundboard mobility for an air humidity in the range [36-46] % (2nd Fang harp)

5. CONCLUSION

This study of 6 Gabonese harps lead to a modal and frequency analysis of their soundboard in order to report on their vibro-acoustic specificities. The Massango and Eshira harps show a similar trend both on conductance maps and via the MVM descriptor with the Massango being globally more mobile in high frequencies. Secondly, on all harps the first 3 bending modes contributions have the highest response and by varying the absolute tuning, harpists may change which fundamental string partials coincide with these contributions thus adjusting the timbre. Regarding the averaged mobilities, both Fang harps show a high variation along string attachment points with a similar trend with a maximum at the fourth string. This indicates that these harps should have a less consistent acoustic radiation from string to string compared to other harps of the corpus. Finally, results regarding the robustness of the MVM to changes in air humidity are encouraging, despite the strong influence these changes have on the local behavior of the mobility through shifts in modal frequencies. The MVM is thus a promising descriptor with a view to on-site measurement and it will be further investigated on a wider corpus of harps in the future.

6. ACKNOWLEDGMENTS

This work, part of the project Ngombi, was funded by the Agence Nationale de la Recherche (French National research agency), grant number ANR-19-CE27-0013-01.

7. REFERENCES

[1] S. Le Bomin, E. Lechaux, and M.-F. Mifune, "Ce que faire ensemble peut vouloir dire en musique," *Cahiers d'ethnomusicologie*, vol. 21, pp. 175–204, Nov. 2008.

[2] J.-L. Le Carrou, D. Bedoya, M.-F. Mifune, and S. Le Bomin, "Acoustique des harpes d'Afrique centrale : Etude préliminaire," in *14ème Congrès Français d'Acoustique (CFA'18)*, (Le Havre, France), pp. 249–254, April 23–27, 2018.

[3] A. Paté, J.-L. Le Carrou, and B. Fabre, "Predicting the decay time of solid body electric guitar tones," *J. Acoust. Soc. Am.*, vol. 135, pp. 3045–3055, May 2014.

[4] J.-L. Le Carrou, S. Le Conte, and J. Dugot, "18th and 19th French harp classification using vibration analysis," *Journal of Cultural Heritage*, vol. 27, pp. S112–S119, Oct. 2017.

[5] J. Woodhouse and N. Lynch-Aird, "Choosing strings for plucked musical instruments," *Acta Acust. United Ac.*, vol. 105, pp. 516–529, May 2019.

[6] E. Skudrzyk, "The mean-value method of predicting the dynamic response of complex vibrators," *J. Acoust. Soc. Am.*, vol. 67, pp. 1105–1135, Apr. 1980.