DOI: 10.61782/fa.2023.0124

forum acusticum 2023

STUDY OF CRISTAL BASCHET'S WHISKERS: SOUND ENRICHMENT OF THE MUSICAL INSTRUMENT

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ABSTRACT

The cristal Baschet is a musical instrument created during the 50's by Bernard and François Baschet. It is composed of a large number of glass rods arranged in chromatic scale. Frictional interaction between wet fingers and glass rods triggers self-sustaining vibrations of the resonator, assembly of metal parts and glass rod, which are transmitted to acoustic radiators. The instrument can be equipped with auxiliary elements to modify its timbre. In particular, long thin metal rods, called whiskers, are commonly added. They act as sound enrichment elements by clearly highlighting some higher harmonics. As the manufacturing process of this instrument relies on empirical knowledge, the way whiskers should be tuned is not well known. This approach is of interest to the instrument maker, since it allows him to understand the dynamic behaviour of whiskers and their interaction with the rest of the instrument.

Keywords: *vibration induced by friction, spectral enrichment, time-domain simulation, musical instrument.*

1. INTRODUCTION

The cristal Baschet (Figure 1) is a musical instrument created by two brothers, Bernard and François Baschet, in 1952 in Paris [1]. The sound is produced by rubbing glass rods with wet fingers, which causes the occurrence of stick-slip phenomenon. Each rod is connected to an assembly of threaded shafts, whose mechanical properties

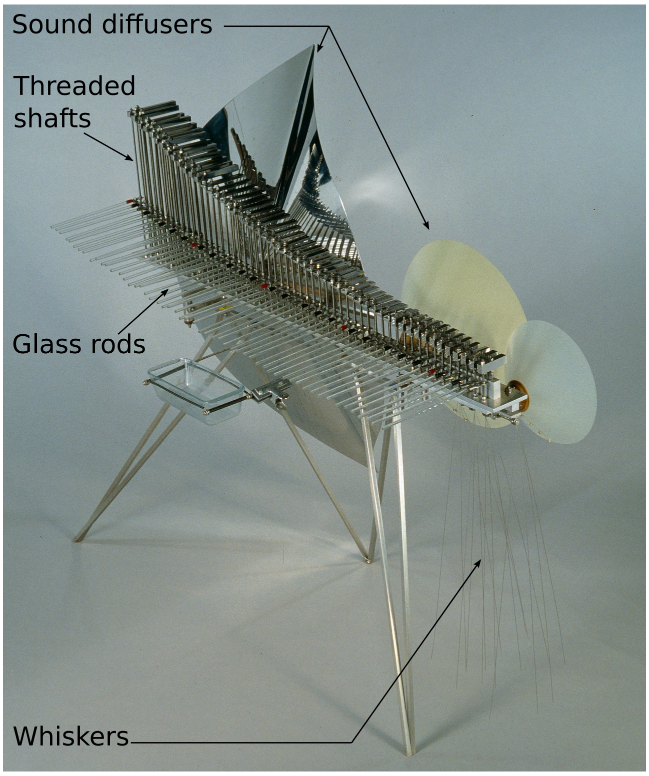

Figure 1. Cristal Baschet with multiple whiskers (pictures freely annotated from Collections Musée de la musique (Paris), taken by Jean-Marc Anglès in 1999, referenced as *cristal, Bernard et François Baschet, Paris, France, 1980, E.983.14.1*).

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determine the pitch of the note. Then vibrations are transmitted to large metal panels or cones that act as radiating elements. Auxiliary elements can also be added to change the timbre of the instrument, like the long thin metal rods named whiskers. The whiskers act as sound enrichment elements by highlighting some higher harmonics. Ones could observe on Figure 2, the sound differences between a cristal played with and without the whiskers. Usually the length of the whiskers is from 1 to 2 m and their diameter is between 0.5 and 1 mm. The manufacturing and tuning of the instrument is essentially based on empirical know-how and involves many parameters. In particular, the way whiskers should be tuned to achieve the desired effect is not well know. Like a previous study of sympathetic vibrations [2], experimental modal analysis and numerical modelling are used. These two methods allow to understand the dynamic behaviour of whiskers and their interaction with the rest of the instrument. First, the dynamic behaviour of the whisker is examined through modal analysis and modelled as a multi-modal linear system. Then the simplified coupled system which is composed of one resonator and one whisker is studied. Experimental measurements are compared with time-domain simulations to gain insight into the role of whiskers and propose tuning guidelines.

2. ANALYSIS OF TUNING CONDITIONS

2.1 Experimental investigations of the spectral enrichment due to whiskers

In order to understand the coupling effect between the whisker and the rest of the instrument, a simplified system is realised. It is composed of a single whisker system connected to the A3♯ resonator (238 Hz) (see figure 3a). The mobility measured close to the connection point of the whisker (point B) reveals a large collection of resonance peaks. The spectral analysis of a recording in point A in playing configuration allows to understand the conditions to be applied to the tuning to produce the sound enrichment (whisker effect). It is shown that one of the modes of the whisker should coincide with a multiple of the playing frequency (which is also the natural mode of the resonator). We observe on Figure 3b, a mode of the whisker around 482 Hz, whose frequency is equal to that of the 2nd harmonic of the signal played. By adding this tuned whisker, the 4th harmonic is highlighted.

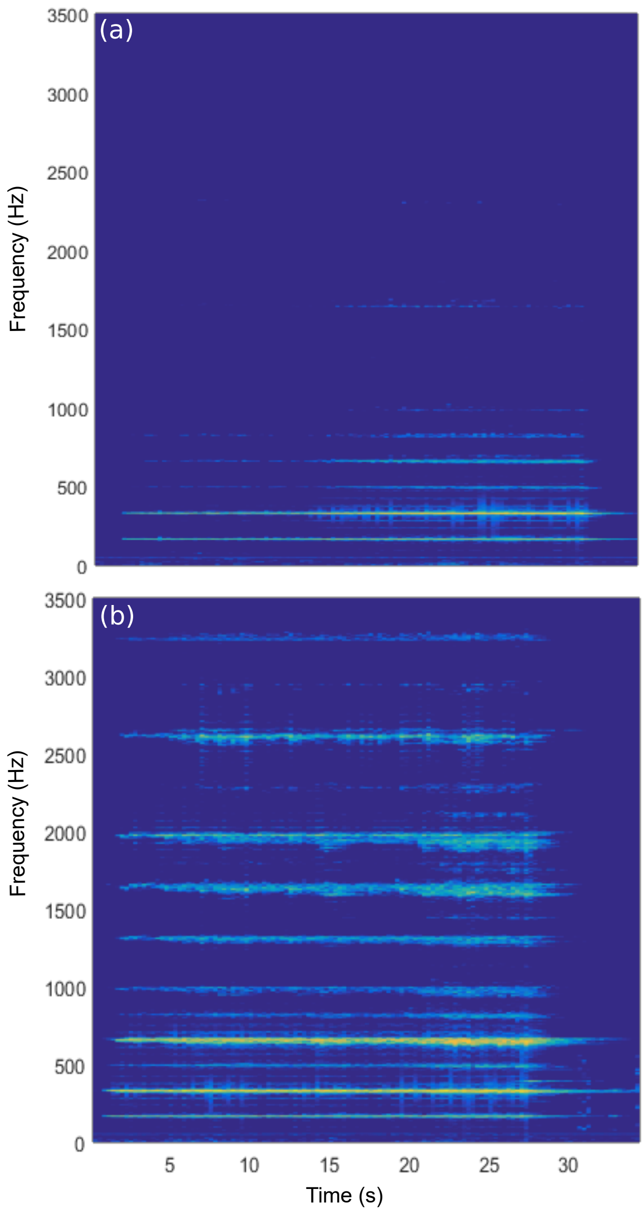

Figure 2. Spectrogram of cristal Baschet played on the E3 note: (a) without any whisker, (b) with a set of whiskers.

2.2 Numerical analysis of the spectral enrichment

A numerical model of the whisker/resonator coupled system is developed to reproduce the condition of the sound enrichment, found experimentally. This coupled model

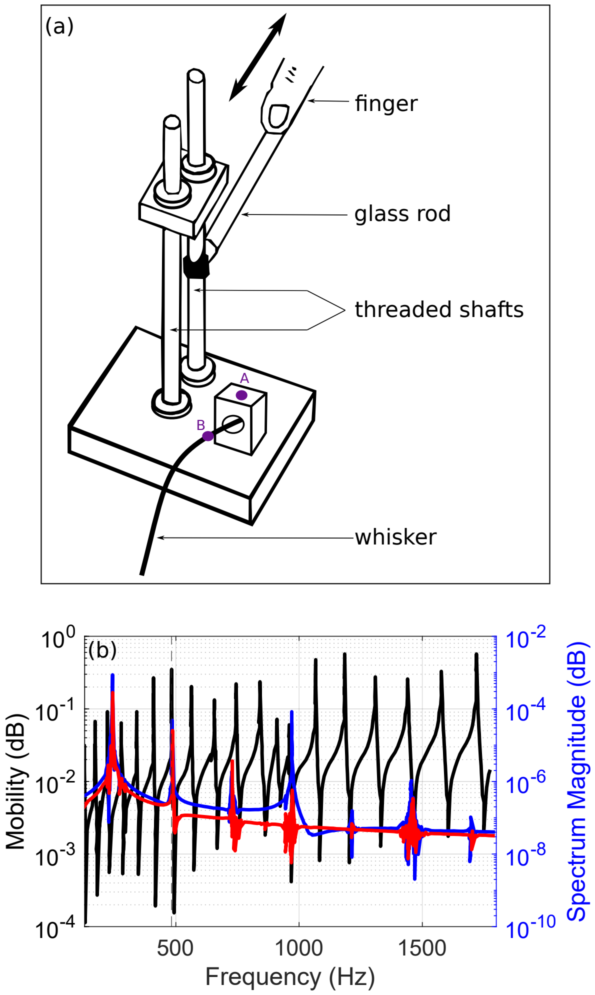

Figure 3. (a) Experimental setup of the simplified system with one whisker connected to one resonator. (b) Co-localised mobility-transfer function of the whisker measured in point B (black line), compared with accelerometer signal spectrum in point A in playing situation: with the tuned whisker (blue line) and without the whisker (red line); there is coincidence between the 2nd harmonic and one mode of the whisker around 482 Hz (vertical dotted line).

takes into account the dynamics of a single whisker, as a multi-modal linear system, connected to one rubbed resonator. A model of rubbed resonator, composed of threaded shafts and glass rod, without any whiskers, has been developed and describes the interaction between one resonator and the musician finger [3]. This study highlights that the dynamics of the resonator is mainly governed by a single mode, when this one is isolated and gives rise to a maximum of mobility. Considering N_w modes of the whisker, the dynamic behaviour of the coupled system can be described by a set of $1 + N_w$ modal equations,

$$\mathbf{M}\ddot{\mathbf{q}}(t) + \mathbf{C}\dot{\mathbf{q}}(t) + \mathbf{K}\mathbf{q}(t) = \mathbf{\Phi}^T\mathbf{F}(t), \quad (1)$$

where $\mathbf{q}(t)$ and $\mathbf{\Phi}$ are respectively the vector of modal coordinates and the modal matrix, which contains the values of mode shapes, $\mathbf{M} = \mathrm{diag}(m_k)$ is the modal mass matrix, $\mathbf{C} = \mathrm{diag}(2\xi_k\omega_k m_k)$ the modal damping matrix, involving damping ratios ξ_k, $\mathbf{K} = \mathrm{diag}(m_k\omega_k^2)$ the modal stiffness matrix involving the natural angular frequencies ω_k. $\mathbf{F}$ is the vector of external forces, which includes the friction force exerted by the musician finger on the glass rod. These modal parameters can be obtained experimentally by a experimental modal analysis. This experiment have been performed on one vertical whisker hanging at its end by the hanging used on the instrument which consists in the compression of the whisker by a screw. A modal analysis algorithm (Least Square Complex Exponential technique implemented in Siemens Simcenter Testlab software) allows us to know the eigenfrequencies and modal damping of a vertical whisker between 20 Hz and 10 kHz.

In order to compare the result given by the experimental measurement, time-domain simulations are performed using an explicit numerical scheme. This explicit numerical scheme originally developed by M. Demoucron [4] for bowed string simulation is adapted for the cristal and has the following form:

$$\mathbf{x}(t_{i+1}) = \mathbf{A}\mathbf{x}(t_i) + \mathbf{B}\mathbf{f}(t_i) \ , \quad (2)$$

where $\mathbf{x}$ is a vector containing all modal coordinates and their time derivatives and $\mathbf{f}$ is a vector containing the modal forces. The coefficients in matrices $\mathbf{A}$ and $\mathbf{B}$ are obtained using a piecewise constant approximation of the right-hand side of modal equations (1). At each time step, the unknown friction force F_T exerted by the finger on the glass rod is obtained by enforcing a sticking or sliding condition.

The A3♯ resonator (238Hz) connected to a whisker is modelled. In order to compare tuned and untuned situations, two different whisker's lengths are simulated (0.8m and 0.9m). The co-localised mobility transfer functions of these two whiskers connected to the resonator are shown in figure 4-a and reveal, as did the experimental analysis, a large collection of resonance peaks. Time-domain simulation is carried out for both situations. The spectral amplitudes of the signal obtained are presented in Figure 4-b and clearly show that the 6^{th} harmonic is highlighted for the 0.9 m long whisker, unlike the 0.8 m long whisker where no particular spectral enhancement is produced. The numerical results thus confirm those obtained experimentally.

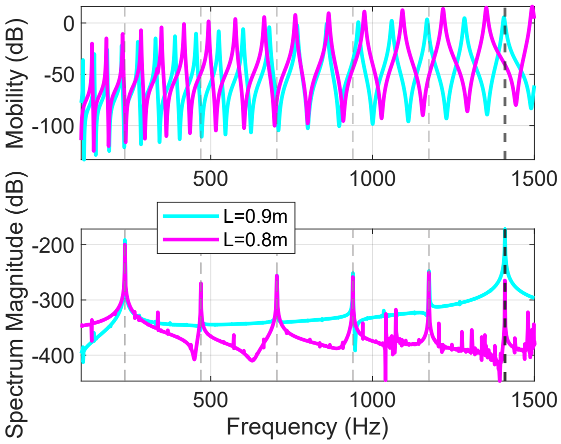

Figure 4. (a) Co-localised calculated mobility-transfer functions of the whisker measured in point B for two different lengths (L=0.8m in magenta and L=0.9m in cyan). (b) Signal spectrum of the calculated velocity in point B in playing situation: with the non-tuned L=0.8m whisker (magenta line) and with the tuned L=0.9m whisker (cyan line); With the tuned whisker there is coincidence between the 6^{th} harmonic and one mode of the whisker around 1409 Hz (vertical dotted line).

3. CONCLUDING REMARKS

The whiskers of a cristal Baschet is a thin rod attached to the resonator support. Its role is to enrich the sound by modifying the auto-oscillation regime. The analysis of a minimal coupled system comprising a single whisker and a resonator is studied experimentally and the results are compared to time domain simulations. These results give the necessary conditions to produce a spectral enrichment: this one occurs in particular when the frequency of one mode of the whiskers coincides with a multiple of the resonator frequency.

4. ACKNOWLEDGMENTS

The authors thank G. Deniel, V. Dorey, A. Laboulfie, S. Lemieux, L. Tricaud, students at ENSIM engineering school, and F. Foucart, LAUM engineer, for the experimental setup and experimental exploration. The authors thank also M. Dauxais, student at Paris-Saclay University, for applying the numerical model and experimental measurements.

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