VIBRATIONAL AND ACOUSTICAL RADIATION IN TWO ITALIAN HARPSICHORDS OF XVII CENTURY

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Abstract
In this paper two ancient harpsichords belonging to Tagliavini private collection have been studied. Different techniques have been utilised, and interesting results have been obtained, especially from acoustical radiation and loss factor.

INTRODUCTION

The restoration and conservation of ancient string instruments is a really complex matter. When the instruments we have today were made, their masters knew all the secrets of wood, of metal and of a good construction. They didn't leave a large amount of books, what they knew was (sometimes) handed on to their disciples through work and not through writings.

Today the situation is quite different: there are masterworks that survived through the centuries and from these objects it's possible to get the secrets of their construction and to improve the knowledge about their conservation and restoration. A relevant role is played by acoustics, which, with its great improvements in technology, can today give a lot of information about the behaviour of soundboards, of strings and their interaction in sound production. In this work, soundboard behaviour of two Italian harpsichords of XVII century was analysed, as an example of how acoustics can provide information about historical instruments.

THE QUESTION OF CONSERVATION AND RESTORATION OF MUSICAL INSTRUMENTS

Historical musical instruments, especially if keyboard instruments, have usually had during their life a lot of rearrangements and variations. The first problem is if it's right to take them back to the original state (or what is thought to be the original state), or to conserve them in the actual one, because each historical state has its own importance.

Collaborations between historians, organologists and restorers become necessary. The first two categories must provide all possible information about historical aspects, and the last has to improve it with its experience in construction and materials. A keyboard instrument presents, unlike most of the other classes of cultural assets, a really wide range of materials: wood, metal, ivory, bone, cloth, paper and paint. A restorer has to deal with this large amount of technical notions, together with knowledge about the different construction times and schools, with their characteristics.

Restoration has been conceived in the last definitions as the necessary intervention to bring back the instrument to be able to sound. This gives raise to a lot of polemics, because instruments are often too fable today to support string tension and a constant use, so they need a necessary strengthening of some parts. On the other hand, a too strict conservation, which doesn't allow any kind of intervention, if not that necessary to preserve its actual state, can lead to the excess of conserving instruments in glass cases without any interaction with spectators. A lot of museums today are of the idea of building copies to try to reconstruct the original sound, leaving the historical instruments in their actual conditions.

However, the fundamental question is always that of a deep knowledge of the instrument, in its history, in its making and in its state, before any kind of decision of intervention, and today a lot of developed technologies are available for this.

THE TWO HARPSICHORDS

The instruments belong to Luigi Ferdinando Tagliavini's private collection, which contains a lot of different types of string and wind instruments.
Giovanni Battista Giusti of Lucca made the first harpsichord in 1679 in Ferrara. It can be considered the "prince" of the collection, for its high sound quality and its external beauty.

Harpsichord craft reached its best period in Italy from XVI to XVIII century. In all Europe there was a great demand for Italian harpsichords, which had different characteristics compared with their cousins of other national schools.

Their sound was sharper and ideal for accompaniment, due to their light structure. The strings doubled their length for each octave, with exception of the last strings in the low register, so that their tail is long and slender ("just scale"). They usually had only one keyboard and two registers, the two of 8'. The instrument made by Giovanni Battista Giusti is particular in the fact that it has three registers, the two of 8' and one of 4', so there are two bridges on the soundboard and three orders of strings for each key. The case is simply painted in turquoise, and the paintings on the lid should belong to Giuseppe Zola, probably in the first years of XVIII century. This instrument has been restored in 1974, but only for little details, it was already in excellent conditions.

FIG.1. The harpsichords by Giovanni Battista Giusti (left) and Mattia di Gand (right).

The second instrument analysed was made by Mattia di Gand in 1685. Mattia di Gand, in despite of its provenience, always worked in Italy, becoming a great constructor of Italian harpsichords. This instrument has been subjected to different variations during its life, the most important of which was the enlargement of the keyboard from 53 (the usual compass of that period, which is also the Giusti's harpsichord one) to 60 keys, with the consequent rearrangement of various parts. The first arrangement which took the keyboard to 55 keys was probably made by the same constructor, for some elements were already built with the idea of extension [1].

These two instruments have been chosen for their similarity in dimensions (their length is respectively 235 and 244.7 cm), for the absence of the rose on the soundboard, and for the very near construction time.

THE MEASUREMENTS

The kind of measurement here used isn't invasive at all. The instruments haven't been disassembled in any of their parts. The rooms in which they are conserved, and where the measurements took place haven't any particular acoustical setting. The measurements were conducted in the same way for the two instruments.

THE FIRST VIBRATIONAL ANALYSIS: ACOUSTICAL RADIATION

Acoustical radiation was studied as the ratio between the sound pressure recorded by the phonometer and the velocity of vibration on the soundboard revealed by the accelerometers (p/v). There has been a similar study on pianos made by N.Giordano in 1998, which inspired this kind of research [2]. A general average of the behaviour of each instrument has been made, and from these graphs a first difference between the instruments can be pointed out.

In Giusti's harpsichord the maxima of acoustical radiation can be observed already before 1000 Hz, and they continue up to about 2000 Hz. The higher zone of emission is at 1200-1300 Hz. A

general average of the behaviour of each instrument has been made, and from these graphs a first difference between the instruments can be pointed out.

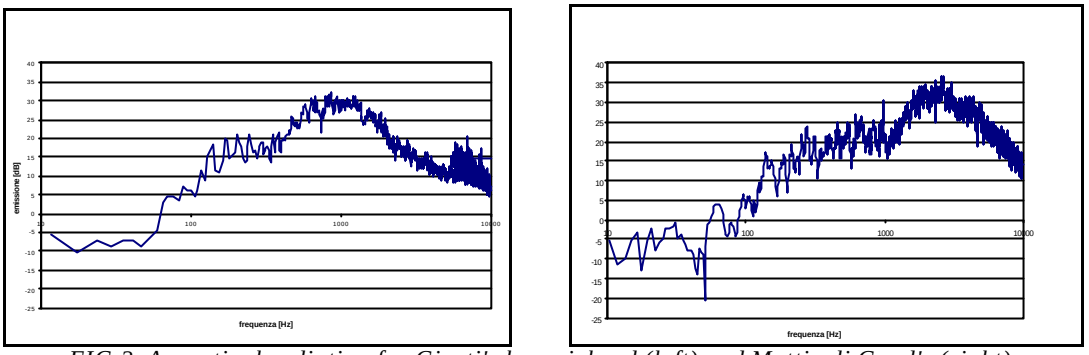

FIG.2. Acoustical radiation for Giusti's harpsichord (left) and Mattia di Gand's (right).

In Giusti's harpsichord the maxima of acoustical radiation can be observed already before 1 kHz, and they continue up to about 2 kHz. The higher zone of emission is at 1200-1300 Hz. In Mattia di Gand's instrument the maxima are at higher frequencies, between 1500 and 3000 Hz. The lowest values of acoustical radiation can be found in the lowest frequencies for both the instruments, about 80 Hz.

THE SECOND VIBRATIONAL ANALYSIS: MODAL ANALYSIS

Modal analysis is achieved through the study of the transfer functions, given by the ratio between the signals of the accelerometer and those of the impulse given by the hammer. In Giusti's harpsichord 34 vibration modes have been found up to 800 Hz, in Mattia di Gand's 27. The first mode of both behaves as a "drum-head", all the zones are in phase (fig.3); than the various parts of the soundboard begin to differentiate, with a general increase of the movement increasing the frequency.

THE THIRD VIBRATIONAL ANALYSIS: LOSS FACTOR

The loss factor indicates what fraction of the vibratory mechanical energy is lost in one cycle of the vibration [3]. In the case of little dampings, as it happens on the soundboards, it's measured from the decay times of the transfer function already mentioned before. A map of the damping behaviour of the two soundboards has been drawn for each point from where the impulse was given.
Comparing the results for the two harpsichords, Giusti's one has a more uniform behaviour all around the soundboard, its values don't cover a great range as Mattia Di Gand's ones do.
Watching the maps of the modes and those of the loss factor, there often comes out a correspondence between the zones on the table that move more at the mode frequency and those which damp faster the vibration.
Comparing the graph of the transfer function used for modal analysis, and that of acoustical radiation, the frequencies of maximal radiation often correspond to minima in transfer function, so that the frequencies of better acoustical emission are not the same as those of greater transversal movement of the soundboard. This result is the same for the two harpsichords (fig. 5).

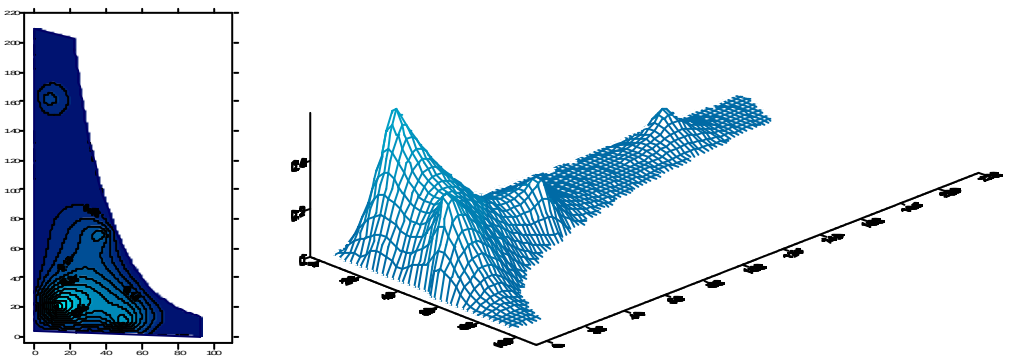

FIG.4. Map of mode n°1 for Giusti's harpsichord (left) and its development in three dimensions (right).

COMPARISONS WITH ACOUSTICAL RADIATION

A similar result was found by H. Suzuki in a work about pianos [4], where the resonance frequencies didn't coincide with those of acoustical emission, on the contrary they were often in antithesis. The other possible comparison is that with loss factor, made through the maps (fig. 6). The areas that emit more sound (in these maps the most coloured) correspond quite well to those, which have a smaller damping.

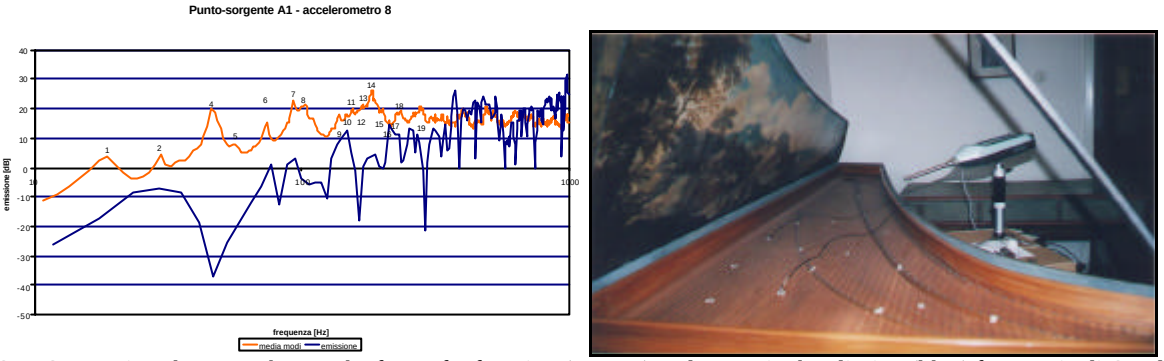

FIG.5. Comparison between the graph of transfer function (orange) and acoustical radiation (blue) for Mattia di Gand's harpsichord (left). Measurements in Giusti's harpsichord (right).

CONCLUSIONS

This work can be an example of how two historical musical instruments can be characterized not only in their physical appearance and state of conservation, but also in their main original function: sound production. Having knowledge of a certain present situation, it can be easily related with successive measurements, so to understand how sound production changes in time, or after a restoration intervention.

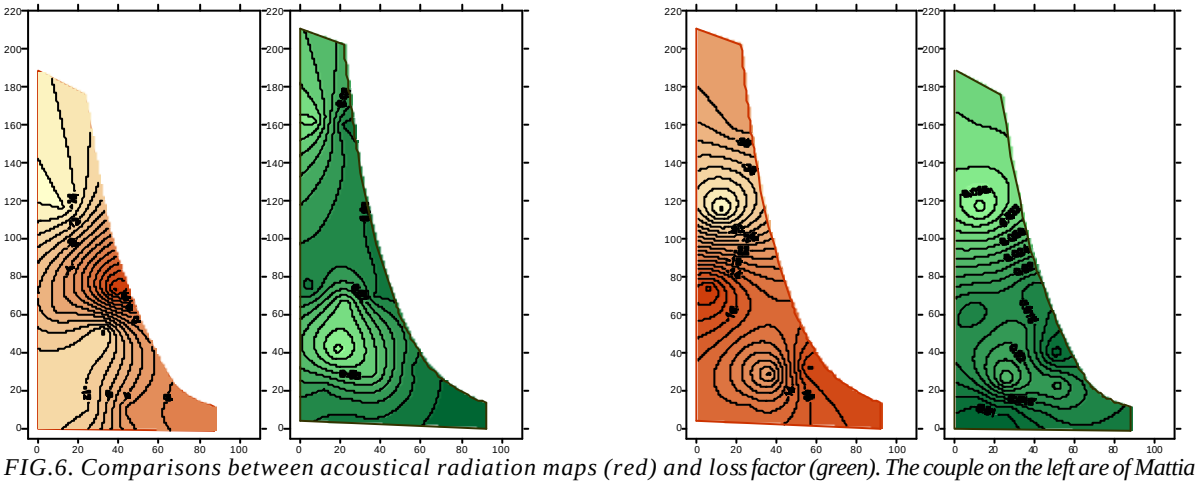

FIG.6. Comparisons between acoustical radiation maps (red) and loss factor (green). The couple on the left are of Mattia di Gand's harpsichord, that on the right of Giusti's.

For those reasons, the cooperation between organologists, restorators and acousticians is always more requested, in order to achieve a better and deeper knowledge of these important witnesses of our musical culture.

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