Spectral Analysis

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Spectral analysis of the behaviour of an acoustic bridge applied to a piccolo

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Overview

It is a well-known fact that professional musicians do not let up on their effort towards improving the aural quality of the instrument that they play. In addition to this, they strive towards making musical performance as simple as possible. The aural vibration that is produced by the embouchure of the piccolo does not just travel through the inside of the body, through the air, but it also transmits via the cylindrical-conic structure, made of metal or wood, that the instrument consists of. The parts that form the piccolo join together and produce interruptions on the path followed by the vibration. An acoustic bridge situated in these linkages would make the vibration transmit itself in a different way, contributing towards a change in the overall sound.

In this work, the acoustic spectrum produced by a piccolo with and without an acoustic bridge is analysed. Several notes belonging to different ranges have been analysed and the reason for the improvement in sound quality that use of the acoustic bridge produces has been physically tested.

Keywords: Piccolo, piccolo flute, acoustic bridge, tone, sonority.

Introduction

A piccolo flute (piccolo), in particular, a piccolo flute from the "Boehm flutes" family, has two parts: the upper part or head, with a hole where the mouth of the player is located, also called the embouchure, that has a sealing cap with an adjustable seal on its free front end; the other part, called the body, has a series of holes for the fingers and key mechanisms (Figure 1).

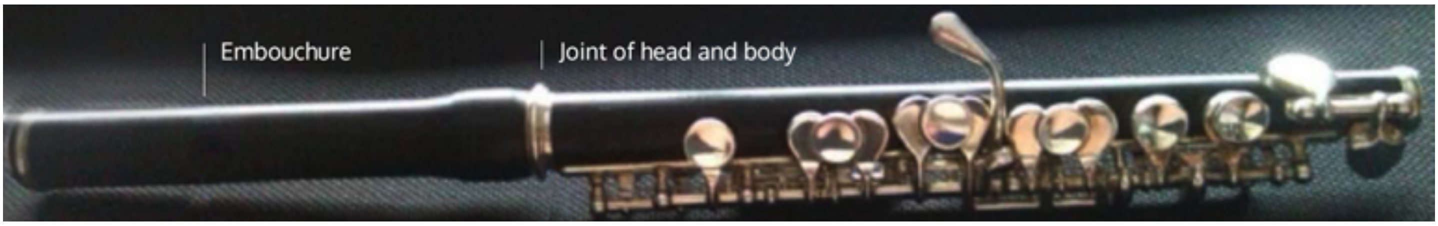


Figure 1 Piccolo. This shows the upper part of the opening (embouchure), the joint between the head and the body, and the body with keys that cover over the holes.

The head of the piccolo is of a cylindrical shape, whilst the body has a conical shape. On the joint of the head and the body where the vibration transmits across the structure, a certain mismatch can be observed. As with electricity, where a short circuit allows for the electrical current to pass through it, that is to say, it provides an easy path for electrons, an acoustic bridge, when applied to the acoustics of instruments, is a device that when placed at the joint of two parts of an instrument, allows the vibration to pass through from one part to another. In Figure 2 we can see the shape of an acoustic bridge [1].

Figure 2 From left to right: A lefreQue acoustic bridge [1], a detail of the position of the acoustic bridge and a general view of the piccolo with the acoustic bridge situated on the joint of the head and body.

The tone of a sound is the subjective characteristic that makes it possible for the ear to distinguish between two sounds, of the same fundamental frequency and intensity, emitted by sources of a different nature [2]. Thus, for example, our ear is capable of distinguishing a $La2$ emitted by a flute from a $La2$ emitted by an oboe. As such, when instruments emit two sounds of the same frequency and intensity at the same time, the notes emitted from each of them can be distinguished perfectly. The sound emitted by an instrument is not a pure tone but rather it is a composition of several frequencies with one of them being fundamental and the rest multiples of that frequency, known as overtones. Hence, the explanation of the meaning of the tone lies in the group of overtones or frequencies that accompany the fundamental frequency.

In the stationary state of a sound, the tone depends on the distribution of the frequency's sound power, in other words, on how the sound power is distributed between the fundamental mode and its overtones. For a power spectrum with components $Pi\ fi$), the spectral centroid fc is a frequency that is defined as follows:

$$f_c = \frac{\sum f_i\ P_i}{\sum P_i}$$

The definition has a similarity to that of the centre of mass. Many investigators maintain that the tonal quality or brightness is correlated with the increase in power of high frequencies. The hypothesis is that the brightness of tones is simply correlated with the fc parameter [3] [4].

2 Methodology & Results

Achieving the results of experiments, as much in the open field as in controlled conditions, is a powerful source of validation for theoretical models. However, the growing interest the study of acoustic waves has brought about the need to achieve experimental measures in complicated conditions. The experimental set-up used to carry out experimental measures used in this work have been carried out in controlled conditions, in an anechoic chamber belonging to the Centre for Physical Technology at the Polytechnic University of Valencia.

An anechoic chamber is a room designed to absorb the sound that strikes its walls, floor and ceiling, cancelling out the sound's effects of echo and reverberation. It should also be isolated from outside, thus cancelling out possible noise from sources outside the chamber that could distort results. This all allows for a simulation of the acoustic conditions in the open field. The size of items and the range of frequencies that can be analysed depend on the dimensions of the chamber. In our case, the chamber that we are using measures de 8 x 6 x 3 cubic metres.

Figure 3 shows the layout of the chamber and the availability of the different elements used to carry out the procedures. The microphone is connected to an analyser where the time signal is recorded and then afterwards, the Fast Fourier Transformation (FFT) is carried out. This analyser is connected to a computer (PC) where results are shown. In addition, there a robotised, three-dimensional system used, for microphone positioning and the movement of the sample (3 DReAMS), synchronised with the data acquisition system.

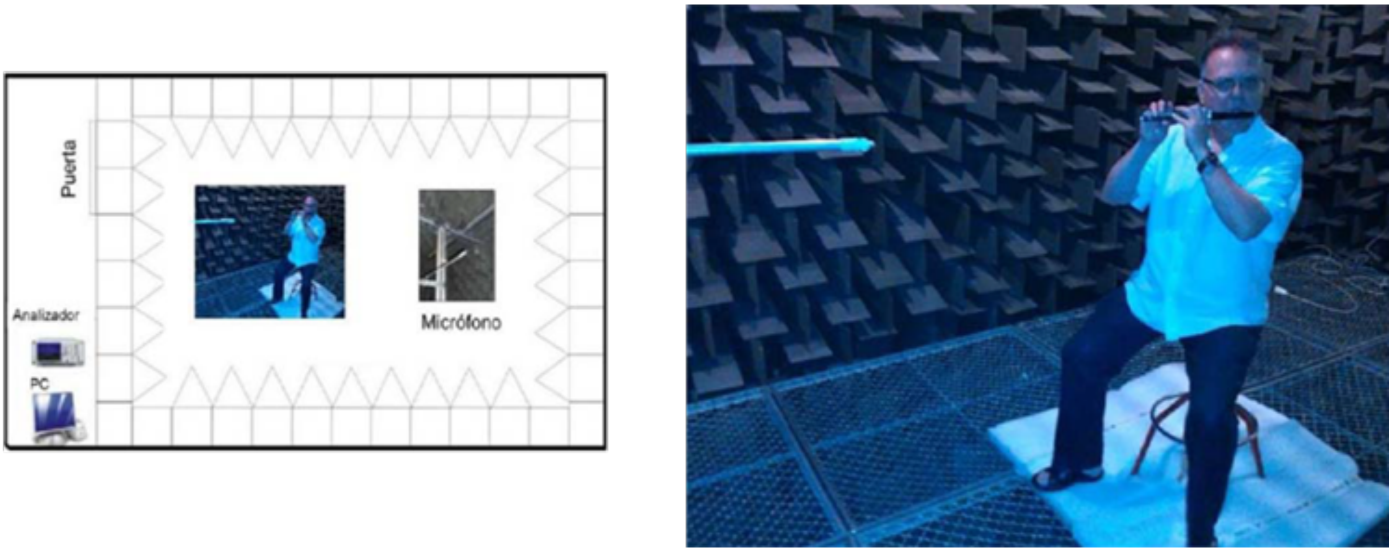


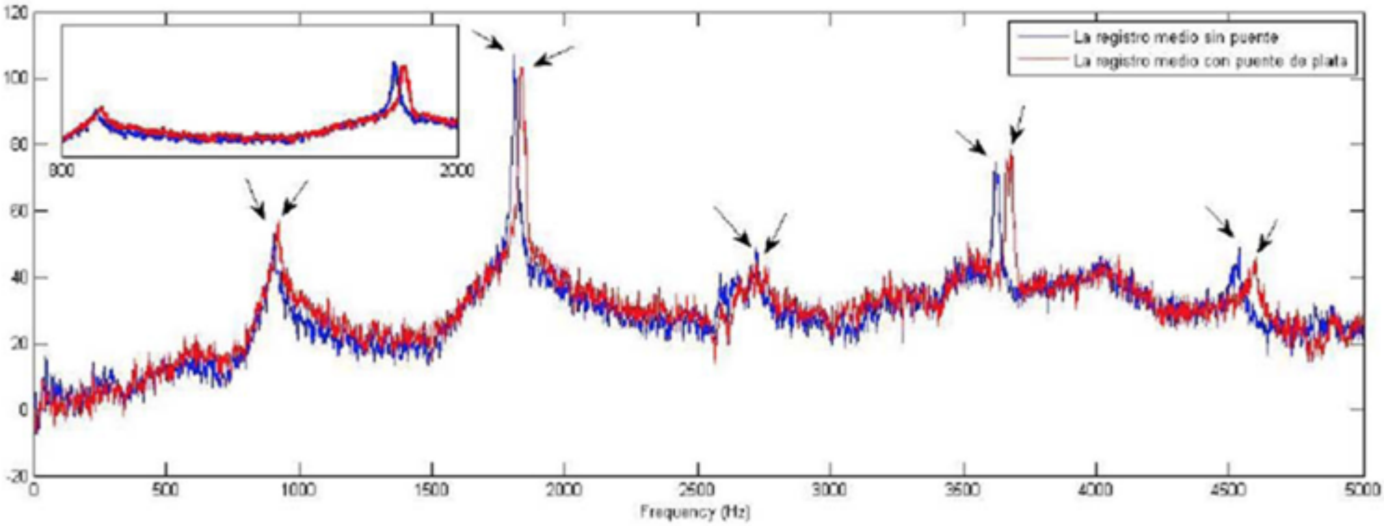
Figure 3 From left to right: Experimental set-up used for the procedures. Relative position of the piccolo to microphone at the time of the procedure. Musician: D. R. Pérez Hernández.

To acquire the data, the PCI-4474 card by National Instruments was used. This card allows for dynamic acquisition of data through 4 channels simultaneously. It is designed equally for the analysis of airborne sound signals as those from vibrations, achieving low distortion and low background noise.

National Instruments cards PCI-4474 and PCI-7334 are used in conjunction with two LabVIEW packages for the acquisition of data and robot movement control, respectively. When the microphone is in position for the procedure, the engines that move the robot's axes are turned off to prevent possible distortions and linkage with the acoustic procedures. Then, the sound source and the microphones are activated, with the latter of these acquiring the time signature. The hardware analysis of this, through an FFT analyser, allows for spectra, frequency response and sound levels to be achieved. The time that passes between when the source starts and the user indicates the procedure is to begin, varying in accordance with the characteristics of the test.

Type 1/2" 4189 B & K pre-polarised microphones were used with a sensitivity of 49.5 mV/Pa, which allow the analysis of a wide range of frequencies.

The procedures were carried out first without an acoustic bridge and then with a lefreQue silver acoustic bridge [1]. Three notes were used for the analysis, one for each range: *La* from the low range, *La* from the middle range and *Re* from the high range of the piccolo. In the three cases, the results were comparable. For example, in figure 4 the spectrum of sound pressure level is represented, with and without the acoustic bridge, for the *La* note of the middle range of the piccolo. In the figure, we can observe the displacement of the overtones towards high frequencies when the silver bridge is used, which brings about a change of tone in the sound. The arrows indicate the position of the central frequencies as much of the fundamental as the overtones. Only the band of frequencies going from 0 to 5000 Hz was taken into account. For the case of the *La* note of the middle range without the bridge, the centroid is located at fc=2624.2 Hz, whilst for the same note but with the silver acoustic bridge, the centroid is located at fc=2672.2 Hz. The tonal quality or brightness of the sound has improved due to the change in position of the spectral centroid, fc, towards high frequencies, as predicted by the theory.



3 Conclusions

The sensations that the instrumentalist said had been noted when he used the acoustic bridge can be summed up as being an improvement in sound quality, with more brightness and greater ease of staying in tune. These improvements are not unfounded since we have seen that physically it is proven that the availability of the acoustic bridge on the piccolo has made the harmonic spectrum change. This change is towards higher frequencies, displacing the spectral centroid and, as such, improving sound quality.

References

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