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Original article

An acoustical measurement used for the understanding of historical wind instruments

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A R T I C L E I N F O

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A B S T R A C T

For conservation reasons, wind musical instruments kept in most of the museums cannot be played. Indeed the musician, blowing into the instrument, causes a violent thermo-hygro gradient that could damage this cultural heritage. Nevertheless, it is interesting to still be able to collect acoustical information about playing techniques or tuning without playing these historical musical instruments. In the museum context when the acoustical value (among every cultural values) is relevant, a facsimile could be ordered to a maker. Less time consuming and less expensive the measure of the input impedance is a good technique to evaluate the acoustical behaviour of reduced to silence instruments. This measurement is used in the Musée de la musique to survey the technical evolution of an instrument family along its history. This article deals with the serpent family. The serpent is a wind instrument which used to be played from the 16th to the 19th century. It was revived in the second half of the 20th century. There is a large variety of serpents (different shapes, different number of holes, provided or not with keys...) kept in the collection of the Musée de la musique. Input impedance measurements show that, despite the geometry evolution and/or the holes number, a common acoustical behaviour can be pointed out for all the family members. The results show that serpents are difficult to play in tune and that all their evolutions (change of shape, addition of keys...) did not bring any improvement in the ease of playing.

1. Research aims

Conservation rules of museums prohibit the playing of wind instruments, which could be damaged by a strong and fast thermo-hygro gradient. It implies that we have a lack of knowledge about the sound and the playing characteristics of these historical instruments.

It is difficult and time-consuming to make a facsimile of an historical instrument so acoustical measurements, and particularly the measure of the input impedance, which is nondestructive and nonintrusive, are useful in that context. At the Musée de la musique, there is a large collection of serpents, an almost disappeared woodwind instrument used to be played from the 16th until the 19th century. By developing an experimental protocol based on the input impedance measurement, this collection is analysed in order to understand the technical evolution from an acoustical point of view.

2. Introduction

In heritage collections each instrument is, most of the time, the only representative left of a style process or an historical period. This is coherent with the museum task which is to present the diversity in makers, making processes, materials, etc. It is thus interesting to study not only an instrument type but its evolution according to the music history or the technical evolution [1]. In addition, conservation rules of museums prohibit the playing of historical wind instruments.

The input impedance, which characterises the acoustic response of an instrument at different frequencies, is thus very useful in this context. The input impedance is usually noted Z and is defined as the ratio of the acoustic pressure (P) at the input and the acoustic volume flow rate (U) into the instrument ($Z = P/U$). By measuring the input impedance, it is possible to find the pitch of an instrument without playing it [2] or to find the length of a missing part of an instrument [3]. It can be used to evaluate the reproducibility of the wind instrument making process [4–6]. It can also be used to characterise the influence of a manufacturing stage, the bending for example [7]. Indeed, the input impedance depends on the

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geometry of the bore and small bore variations lead to different impedances [8, p. 65–67]. As an application, this technique is used to characterise the serpents corpus of the Musée de la musique.

The serpent, whose shape imitates the animal (Fig. 1), is defined in the Grove dictionary [9] as "a lip-energized aerophone with side holes and a cup-shaped mouthpiece invented about 1590. Its original purpose was to strengthen the sound of church choirs, especially in plainchant". Its length could reach 2.4 m and it was almost always made of several wooden half-forms glued together and covered by a thin leather layer which gave its external aspect (later serpents could be made of metal and have additional holes). The position and size of the holes, in comparison with the bore of the serpent, make it difficult to play in tune. It has been mainly reserved to support the plainchant in church music for more than two centuries. However, after the French revolution of 1789, religious celebrations were replaced by national commemorations and thus a lot of musicians were needed to play outside. Since the serpent was no longer reserved for an elite, makers needed to make it easier to play by improving its intonation and ergonomics.

What is a serpent and which kind of instrument can be called a serpent? Does a modification of shape lead to a modification of the sound and playability? In order to answer these questions, to measure the acoustical influence of several evolutions and changes in geometry, and to find a common descriptor for the family, measurements have been carried out on several serpents of the Musée de la musique.

3. Protocol

3.1. Impedance measurement

Many techniques are used to measure the input impedance [10–12]. The difference between these methods consists in the measurement of the acoustical flow. Using one or two pairs of microphones is the most popular technique [13,14]. In this study, the experimental setup developed jointly by the Laboratoire d'Acoustique de l'Université du Maine and the Centre de Transfert de Technologie du Mans has been used [15]. In this system, one microphone is positioned in a cavity behind the source which allows an estimation of the flow. The source is a piezo electric buzzer. The instrument is connected in front of the buzzer via a small cavity in which a second microphone is placed to measure the acoustical pressure. The transfer function between the two microphones, taking into account their sensitivities, allows the estimation of the input impedance.

Fig. 1. "Un Serpent de Paroisse" (a parish serpent), a satirical lithograph by Delaunois published in 1835 in a French periodical.

Fig. 2. Experimental setup used to measure the input impedance of historical serpents.

The absolute uncertainty of the resonance frequencies measurement with this sensor is estimated to be 0.3%, which is 5 cents[1] [16]. However, when comparing different resonances of the same instrument, the relative error is estimated to be ± 3 cents, as systematic errors, such as those due to temperature or sensor geometry, are partially compensated.

The input impedance measurement is sensitive to the air temperature and to the airtightness between the device and the instrument. Silicone adaptors are thus made for each instrument (Fig. 2). These adaptors allow for perfect contact between the device and the serpent and respect the conservation rules (silicone is noncorrosive on both metal and wood). Moreover, the measurements are carried out in a climate-controlled semi-anechoic room in order to avoid temperature changes and interferences. To have reliable and repeatable measurements, it is necessary to firmly affix the instrument flat on the impedance sensor in order to avoid any leak and to prevent it from moving. Nevertheless, due to the objects fragility, the adapters do not stand for a perfect rigid mounting.

3.2. Measurement on historical instruments

The conservation state of the instrument does not always allow perfect measurements because of leaks or material degradation (porosity, holes made by insects...). Therefore, it is important to try to quantify the acoustical impact of the time degradation in order to keep a trace of the original shape of the instrument and understand the maker's know-how [1].

Consequently, the unknowns cited previously show that it may not be possible to reach the level of precision that can be obtained with new instruments [16]. Amplitude of the input impedance measured several times on a same serpent (by removing it from

[1] The cent is a logarithmic unit of measure used for musical intervals. A semitone is divided into 100 cents. The number of cents C measuring the interval from two frequencies f1 and f2 can be calculated by the following formula: $C = 1200 \times \log_2\left(\frac{f_2}{f_1}\right)$.