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INFLUENCE OF DESIGN PARAMETERS ON THE ATTACK TRANSIENTS OF RECORDERS: A PRELIMINARY INVESTIGATION

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ABSTRACT

Self-sustained musical instruments are complex systems, displaying a wealth of sound regimes whose characteristics depend sensitively on a large number of design parameters (fixed by the instrument maker) and control parameters (adjusted continuously by the musician). We focus here on flute-like musical instruments. In the case of transverse flutes, the geometrical parameters of the exciter are largely adjusted by the musician. In recorders and organs, on the other hand, most of these parameters are fixed by the instrument maker. On recorders, moreover, one must play multiples notes on multiple registers using only one pipe, which enforces compromises from the instrument maker perspective. Unveiling the relationship between geometrical parameters and sound characteristic remains a major challenge. Here, in close collaboration with several instrument makers, we aim at identifying the most important design parameters involved in the control of attack transients. We present an experimental setup that aims at improving our understanding of the influence of the key parameters used by instrument makers.

Keywords: *Flute-like instruments, attack transients, instrument making*

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1. INTRODUCTION

In flute-like instruments, sound production results from a the coupling between an exciter constituted by an oscillating air jet and an acoustical resonator constituted by the air column contained in the instrument. More precisely, when the musician blows into the instrument, the pressure difference between its mouth and the instrument induces a flow in the *channel* (see figure 1), resulting in a jet formation in free air at the level of the *window*. Because this jet is naturally unstable, any perturbation is amplified while convected toward the *labium*. The oscillation of the jet around the labium constitutes a dipolar pressure source that excites the resonator. This creates an acoustic field in the resonator, which perturbs back the jet transversally at the window exit. This kind of feedback loop is very symptomatic of self-sustained instruments.

This mechanism, where sound production results from the oscillation of an air jet around a labium is common to all flutes. But in recorder, like organ, and unlike transverse flute, the air is conducted through a windway to the labium. The geometry of the instrument, set once and for all by the instrument maker, determines many characteristics of the instrument. Yet, as there is only one pipe, the recorder maker must make compromises, such that the instrument can be played on its whole *range*. Instrument makers learn through trial and error how to adjust the geometrical parameters to obtain the desired sound characteristics.

Many studies already discussed the influence of geometrical parameters of recorder-like instruments. Ségoufin [1] showed how channel length and chamfers are tuned to improve the playability of the instrument. Terrien [2] showed how the geometry of the channel also influences the range of blowing pressure for which the pe-

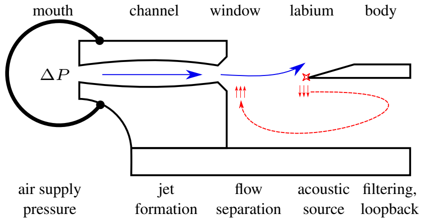

Figure 1. Schematic representation of the sound production mechanism in a recorder
Blue arrows represent the oscillating air jet, red arrows acoustic fields.

riodic sound regimes are stable. Ernoult [3] made significant improvements in the model of the acoustic response of the window of the instrument. More generally, the influence of the geometry of the bore of the flute and the positions of the note holes on the passive resonances are well understood [4].

However, most of these studies focus on the case of quasi static variations of the mouth pressure. Nevertheless, attack transients are known to be a crucial element of the sound [5]. They are also a very important mean of expressiveness for the player. Yet, they are harder to reproduce in a controlled setup than quasi-static variations. Experimental studies on attack transients [6] show that the transition from no pressure to a nominal pressure, using the tongue as a valve, is not only very accurate (almost no over-pressure) but also very fast (around 10 millisecond) and versatile [6]. Using a crossbow valve, Ségoufin [1] showed that chamfers reduce attack transient duration by fostering the development of the first mode of the acoustical resonator. Investigating different mouth pressure ramps with a servo-valve, Terrien [7] showed that mastering mouth pressure dynamics extended the range of playability of the instrument.

Recorder makers already know, at least empirically, the links between these parameters and sound characteristics. But unlike acousticians, they have a global end-to-end approach. They tune simultaneously all the geometric parameters to get all the sound characteristics of a “good” recorder. One may wonder if there are still parameters controlled by makers but unstudied by acousticians and what are the characteristics of this “good” recorder.

We will first describe a method to gather empirical knowledge from recorder makers. We will then present an experimental setup in order to investigate and elaborate on the influence of each separate design parameter on the attack transients of the instrument.

2. GATHERING EMPIRICAL KNOWLEDGE

2.1 Historical Context

The geometry of recorders never ceased to evolve over centuries. A notable example is the shape of the bore, designed to ease the play, with for instance smaller and closer tone-holes, and to extend the range of the instrument, by simplifying the access to the second and third registers of the instrument [8]. But around the middle of the 18th century, the recorder began to decline, maybe because it has not the good range in order to play in orchestra [9]. As a consequence, the recorder has hardly been played or built during around 150 years until the baroque renewal of the seventies [10]. By then, knowledge about recorder making had been completely lost.

It is by studying historical instruments and through a trial-and-error method that recorder makers reinvented this craftsmanship, acquiring by experience a lot of empirical knowledge about the links between the geometry and the qualities of their instruments, which is the core of their work. Indeed, a fundamental difference between a serial industrial recorder and an instrument made by a recorder maker is the time spent on it. On the one hand, the industrial recorder is a ready-to-play instrument: it is designed to be sold directly after going out of the production chain. On the other hand, the recorder maker first makes a “draft” on which he or she will make small geometrical modifications in order to adapt the draft to this precise piece of wood and get the desired instrument.

As this craftsmanship is mainly empirical, there is currently no manual of recorder-making, there is no official recorder-making apprenticeship [1] and generic woodwinds making courses are relatively scarce concerning recorder making and maintenance. In particular, no precise data are available on adjusting transients in recorder making. We turned towards recorder makers in order to 1. identify the main characteristics of attack transients they are looking for 2. identify the geometrical adjustments they consider in order to tune the attack transients. Once gathered, these data could also be useful to provide a written basis describing different recorder-making processes.

[1] Though there exists unofficial ones. In general, makers are very generous concerning sharing their knowledge, see for instance Philippe Bolton’s website.

2.2 Methodology

2.2.1 Participant Selection

For this study, we selected french speaking recorder makers in their native language, in order to be able to compare the used vocabulary. This inclusive criterion narrowed the potential participants to roughly 10 people. As it is a relatively small group, they know each other relatively well, yet there still exists divergences in their methods and approaches. Knowing whether or not these differences influence their relationship with the attack transients of their instruments remains an open question.

2.2.2 Interview Method

In order to acquire data from empirical knowledge, we use semi-structured interviews [11]. An interview outline – the *topic guide* – includes questions, grouped by topic, go from very broad and open questions to more and more precise questions. Beginning with open questions helps the interviewed to feel comfortable. Furthermore, structuring the interview guarantees to address all the expected topics. Finally, it is also interesting to notice whether or not the interviewed addresses a topic spontaneously in the discussion or if he or she had to be queried specially about it. For instance, when queried about the characteristics of a good recorder, three makers naturally said that the attacks were very important. For the other two, we had to specifically ask their opinion about attacks, and they both agreed that it was important. There are also more converging opinions, for instance on the balance between higher and lower notes. They all cited it as an important characteristic of a good recorder.

3. RECORDER MAKING IN A CONTROLLED ENVIRONMENT

As mentioned above, during the recorder-making process, the maker modifies small geometrical features of the instrument in order to obtain the desired instrument. However, studying a recorder being shaped is problematic from the experimental point of view: most of the operations performed on a recorder are not cancellable and testing the instrument by blowing into it is not easily repeatable. So we need an instrument on which geometrical parameters are easily tunable independently from the rest of the instrument and a procedure that can repeat various attack transients on a recorder.

Figure 2. The Modular Recorder's head
left to right: ring, removable ceil with block, head

3.1 A Modular Recorder

A modular recorder (figure 2) has been developed during Terrien's thesis [2] in collaboration with the recorder maker Philippe Bolton. Like every recorder, the floor of the channel is made of a removable part forced into the instrument. But the ceil of the channel, which is usually directly carved into the mouthpiece, is here also a removable part, held by a 3D-printed ring. With both removable parts, one can craft the desired channel geometry (including chamfers and window width) without altering the rest of the instrument. Apart from that, the whole instrument is an instrument from Philippe Bolton's catalogue [12]. The prototype is therefore really similar to an instrument that can be played in concert. This has, however, a drawback: real instruments need regular checkup in order to balance the degradation of time.

3.2 An Automated Player producing realistic attack transients

As already stated, reproducing an attack transient is a very challenging task. An artificial mouth has already been developed in the laboratory (see figure 3). The pressure control is achieved with a PID flow controller. As the characteristic time of this controller is very long (around 1 s), transients are emulated by deactivating the PID feedback loop, and inputting a Heaviside step function. A small reservoir in derivation is put downstream in order to smooth the transient of the mouth pressure. One can adapt the size of the reservoir to obtain different shapes of mouth pressure transient, but it is neither precise nor convenient.

Moreover, in order to have a realistic setup, this automated player must also be able to play notes on the whole range of the instrument. This is relatively hard, mainly because of the left thumb hole. This hole can either be a tone hole (for the upper notes of the first register) but also a register hole. When partially covered, the small leak in the resonator gives access to the second and third register of the instrument, and the player can adapt the size of this leak to each note simply by moving his or her thumb. It can also be used as a pitch hole to compensate pitch loss due to low pressure [4].

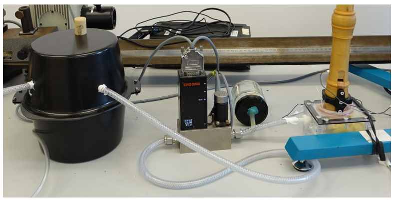

Figure 3. Picture of the player
from left to right: pressure reservoir, flow controller, small reservoir, artificial mouth

Holes are covered with rubber seals tied around the instrument plus a cylinder adjusted to the thumb hole diameter, drilled to a smaller diameter to have the thumb hole partially covered, but it is not very convenient: to change the fingering, one must put the recorder out of the alimentation system. A key-mechanism, just like modern instruments, would allow to change the note without manipulating the flute.

4. CONCLUSION AND PERSPECTIVES

We presented a method to improve our understanding of the relationship between recorder geometrical parameters and sound characteristics of the instrument, based on the knowledge already acquired by the recorder makers through their experience. We first explained the semi-structured interview that we will use to gather this knowledge, then we presented a way to investigate recorder making in a controlled environment with a modular recorder and an artificial mouth.

The next part of our work is to compare the interviews in order to outline the parts in concordance between makers regarding geometrical features and sound characteristics of the instrument. While the first part will give insights on the main parameters influencing the sound, the second one will help us to determine relevant sound characteristics influenced by these parameters. Diverging information in the instrument maker answers may also give us insights about the different strategies of recorder-making that could explain the signature of a recorder-maker on each instrument. We will then have to improve the artificial player to gain a finer control on its mouth pressure transient. Finally, there are still unsolved problems such as the air humidity.

As we mainly focus on the influence of making parameters, we overlook some other aspects of the control of the musician. This includes the influence of the player's vocal tract, although the cavity of the artificial mouth is already adaptable. However, an improved artificial player could help to investigate other open questions. For instance, is it possible to emulate the effects on the sound of different kinds of human attack transients only with a fine control of the mouth pressure transient ?

5. ACKNOWLEDGMENTS

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