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Generation and conception of measuring tools for geometrical and acoustic properties for modern Almenräder-Heckel system bassoons.

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Abstract

The bassoon is a complicated instrument that is still requiring a large quantity of research[1]. As a result, data on the instrument's design is scarce [7]. The main objective of this project is to create tools capable to provide trustful and detailed information on different structural and acoustical characteristics of modern bassoons that will be included in a database. Different types of data are included such as precise bore measurements obtained with a new measuring bench, tone hole measurements, impedance measurements, sound recording with an artificial mouth and description of the instrument's timbre from the owners. The geometry is then entered on the PAFI (Plateforme d'Aide à la Facture Instrumentale), where impedance calculation can be compared to measured ones. We want to trace the evolution of the Almenräder-Heckel bassoon over the last century through a cross reference of all the acoustic data gathered.

Keywords: Bassoon, Measurement, Acoustics

1 INTRODUCTION

This presentation takes place as part of a doctorate study at Montreal University. The goal of this study is to obtain diversified acoustical properties of modern professionally played bassoons. We target a large quantity of Almenräder-Heckel system, typically know as the "German" bassoon. This presentation will focus on the methodological aspect of the study, therefore the choice of acoustical properties, their chosen measurement methods and protocols. As of today, some tools have been tested on a single bassoon, in preparation for larger scaled data acquisition.

2 THE BASSOON

2.1 Historic

The history of the bassoon is vast, but a major turn took place in the 19th century. At the time, the acoustic world became familiar with new concepts which will also lead to changes in instrument making. Such evolution includes the addition of register holes and the removal of forked fingerings. Around 1795, the first register clefs appears on what will become the "Buffet system" bassoon (or the french bassoon). Buffet, with Jancourt's major contributions, will slowly work toward meeting new musical expectations. On a different path, we find the acoustical publication of Gottfried Weber, which will be used by Charles Almenräder. In 1824, Almenräder will publish a study on the perfecting of the bassoon. In 1831, he will join Johann Adams Heckel, wich will mark the beginning of today's leading German bassoon maker, Wilhelm Heckel GmbH. As pointed out by multiple studies on the bassoon, this change goes toward Boehm's theories of the "right tone-hole placements" principle, and the key system to hold open all subsequent keys principle. As pointed out by Jean Kergomard [1], the bassoon is actually a hybrid-semi-Boehm instrument. The first principle is applied, but only in the lower register of the instrument, mostly in the lower extension. The second principle is used only partly, with the low Bb key help open, the adding of correction holes and "resonance" holes, opened by ring keys. Around 1905, we see a bassoon with a full key system, including a separately operated bocal key (whisper key).

Both instruments were successful on a professional scale, mostly until the passing of the renowned french player and teacher Maurice Allard in 2004. The popularity of the "French bassoon" began to fall. This tendency is the reason why this project will solely focus on acoustical characteristics of the Almenräder-Heckel system. Is the "German bassoon" design still being pushed by science? Most German bassoon makers seems to share a more traditional approach. Are there anyone trying to make another bassoon revolution? There are lists of experimental bassoons, or other instruments that were given birth trough trials, prototyping and application of parallel ideas. There are many instruments that are different variations of the bassoon: the heckelphone, the sarrusophone and the logical-bassoon are simple examples of them. You would never see one of those replacing a first chair bassoon in any major classical orchestra, unless specifically requested. The famous instrument makers seems rather sceptic a introducing any drastic changes. Does the bassoon need to evolve? The instrument has many issues and solving them could help musicians.

2.2 Fundamental acoustic properties

What is the bassoon? This project will try to answer this question. We need to know what has to be adapted or kept in order to know what can change. We think that the answer lies within the bassoon itself, within its evolution. We will record the sound of the instrument, measure its geometry, measure and calculate its impedance response and finally, we will collect a description of the sound by the owner. We hope that, through the analysis of these characteristics, we will be able to find tendencies. Those tendencies should evolve toward certain line that should correspond with the growing needs of performance. Therefore, we should be able to correlate sound characteristics with geometric changes. These correlation will help us understand what is the essence of the bassoon, and at some point, propose an idea of what it could become if these tendencies are preserved.

3 METHODOLOGY

3.1 Acoustical properties measured

3.1.1 Sound recording

As mentioned, we want to have a recording of all the measured instruments. This recording isn't meant to represent and exact playing situation, but to confer comparable data between instruments. As such, we have decided to change the musician with an artificial mouth. We also have decided to use a "Légère" reed. These decisions are all taken in order to respect a proper degree of repeatability.

3.1.2 Geometry

We need a proper geometrical representation of the instrument. At first, we taught of the use of tomodensitometry (CT-scan), but the need of mobility makes it less practical. We have opted for a measuring bench recommended by Patricio de la Cuadra, whom has made one for the traditional flute. This bench will be able to measure the bore and tone-hole placements. Tone hole sizes and length will be measured with a set of graduated mandrels. The bocal's bore, being too small for this kind of measuring tool, will have his impedance measures and it's geometry calculated.

3.1.3 Impedance

The addition of the impedance in this study is not as straight forward as recording of the sound or geometric measurements. We would like to find relations between say; a specific sound characteristic, it's geometric reason, and an impedance trace of the phenomenon. We would like to gather these relations and eventually use them in prototyping.

3.1.4 Inner bore recording

It was proposed to include recordings of vibration inside the bore, in order to avoid influence by the environment. We dismissed the idea. To realize the project of collecting data on a large quantity of instrument professionally used, we need to shorten the amount of time the whole process will take. Also, we try to avoid as much intrusive manipulations are necessary.

3.2 Tools and protocol

3.2.1 The artificial mouth

With the contribution of the Jean-Pierre Dalmond at LAUM, we have designed an artificial mouth for the bassoon. It firstly runs on an input of pressurized air going through a gas regulator. Next, the air goes to a rotameter to measure the flow of gas. The line is then split, where one part is connected to a water tower. The air comes from the top section of a tube bent in a "U" shape, with the second end opened at the top. The pipe is filled halfway with water. The air will then exhort a force on the water, which will push it through the pipe. We measure the difference of the water level on both parallel sides of the tube, giving us the ΔP. Each cm of water level difference corresponds to 0,1kPa (1mBar) of air pressure. Changes are then made on the regulator until the desired pressure is reached.

The other side of the split is connected to an overpressure valve. This device was added to prevent potential surges of pressure provoked by the start of oscillation of the reed, or it's changes of oscillation regime. This design has the benefits to be cheap, sufficiently precise and easily re-creatable. A major counter part is that the water in the tower moves rather slowly. If a major change is made too swiftly to the air pressure, the air will compress until a balance is regained from the force of the water pressing on the other side of the tower. If too much pressure was allowed, the water can sprinkle from its free top end.

Following the valve is a fibreglass cylinder, closed at both ends, fitted with a removable sealing cap that is made of a pliable rubber able to squeeze around an object (the reed). The pressured air pass through the reed that is covered by a pair of artificial lips. A technician creates the desired fingerings. A microphone is set at exactly the same position for every recordings, that sends a calibrated signal to a sound card, connected to a computer to save all data.

The main reasons for using this design are: 1. We can transport all the equipment to the musicians, which will allow for a greater number of participants. 2. Most parts are widely available, allowing for easy repairs/adjustments. 3. It gives a consistent and repeatable playing situation. We do not recreate the exact sound of a musician but will not get any modification/correction either. We have also found that 4,3kPa was an optimal air pressure that allowed the tested bassoon to easily reach its whole register (from B♭1 to E5). Any lower than this amount was not sufficient to hold higher oscillation regime where any higher than this amount forced the second oscillation regime while attempting the low register (mostly from F2 downward).

3.2.2 The reed

It is mandatory to choose and calibrate the excitation method. In this case, we avoid potential instability of the wood by using the "Légère" reed. We focused on the calibration of the artificial lips installed on the reed. This diagram shows three spectrum curves of the sound of a reed that was set for the low register and connected to a bocal. As the reed was held by a rubber surface, the holding of the reed by a bocal helped stabilizing the movement of the reed that was unbalanced by the weight of the artificial lips. It also lowered the emitted fundamental frequency. A first signal was recorded and set as a goal, while the other two were the results of a setup dismantle and reassemble with about 5 minutes of calibration each.

There are three main characteristics on the pressure applied to the reed, excluding the air. The first is the placement of the lips on the reed in a front-back axis. Second is the pressure applied by those lips. Finally, the "shape", or the distribution of the force applied on the reed, whether evenly or irregularly applied. We have to set the lips properly in order to recreate the same signal for every instruments. As shown in the repeatability figure, we were able to recreate a very similar excitation source that allows comparison of different

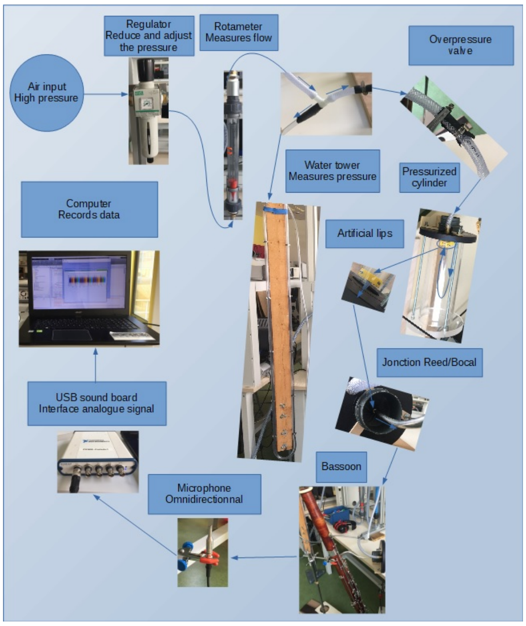

Figure 1. Diagram of the artificial mouth's configuration

instruments. While we physically move the lips ever so slightly, we were able to see great changes in the calibration measurements. This results makes the adjustments efficient since it means that, for the signal to be similar, it required a great physical resemblance. We could hardly find a difference between the analysed results multiple recordings with out without dismantling the reed. Therefore, we do not think necessary to measure the physical pressure with any sensor. We have yet to establish the off-set limits that would cause a perceivable differences in results (how close do we need to be from the original signal). We mostly rely on the fundamental frequency, the hight of the first peak and the spectral gravity center to guide the changes needed.

As shown above, a lip placement toward the tip will help reaching the lower register of the instrument, while a placement closer to the shoulder will allow changes in regimes. It is important to note that, the very tip isn't suggested with artificial lips, since their control isn't as precise as real lips (a musician's lips does not need pressure on the reed to be held in place). Thus, the optimal placement is to leave 1mm of the tip free of material. The pressure needed to obtain the low register was so low that silicon was opted out as a lip material. We replaced it with pieces of foam. The reed was almost able to vibrate properly but, the contact friction was so low that the lips would slide and fall out of position while the system was vibrating. We added a small layer of sticky patty to enhance the placement stability of the lips. This test revealed that the patty could help altering the shape of the pressure applied on the reed. Therefore, we changed from an even layer for the addition of two spots near the "magic windows" of the reed, recreating an "O" shape of embouchure. The distribution of the force (the shape of the contact surface) and the placement of the lips mostly affect the brightness of the sound, measurable with the SGC, while higher pressure will mostly rise the fundamental frequency.

3.2.3 Measuring bench

We gather information on the diameter of the bore (y) at all positions (x) of the air column with a specialized measuring bench. The bench holds a bassoon part, while a tool head slowly moves along the inside of the bore. This head is screwed at the end of a tube, used as an extension made to fit through the smallest bore diameter at the top end of the wing join and long enough to cover the longest part of a traditional long joint. The tool head has two arms installed opposed to each other, fitted with a roller to serve as contact point with

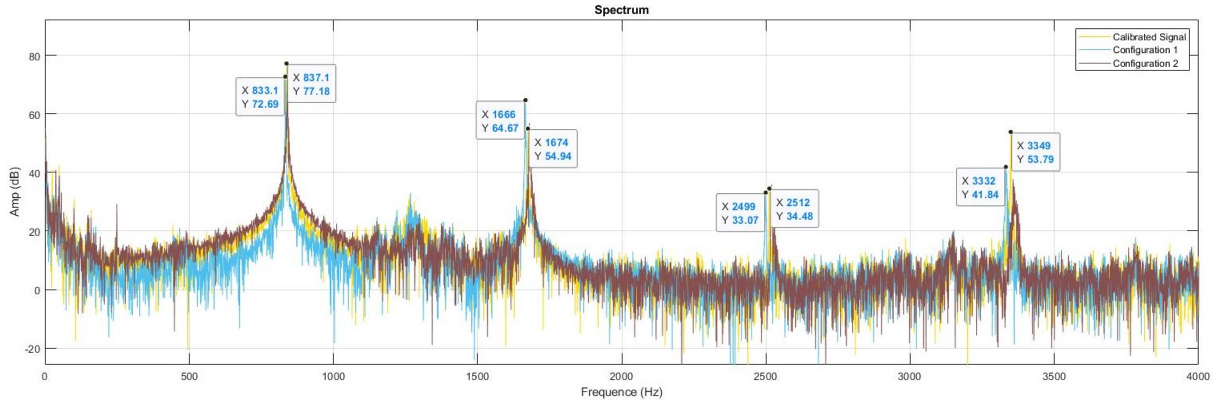

Figure 2. Repeatability test of artificial lip configurations

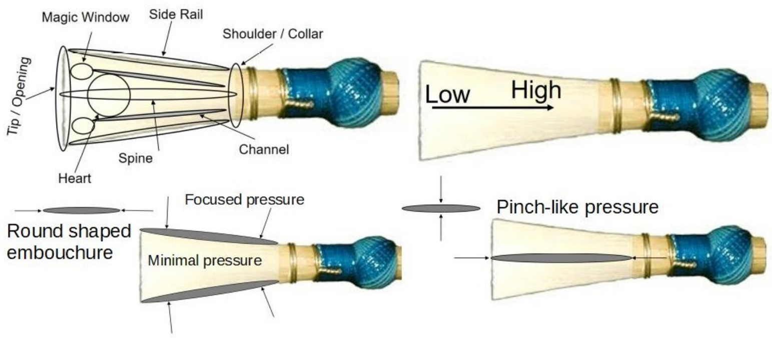

Figure 3. Diagram of characteristics of a bassoon double reed

the instrument. The use of a roller prevents any potential markings. The two arms have a pointy shape towards the center, pressing against a triangle piece. While the arms moves toward the center (in the case of the bore getting smaller), they push the triangle outside, thus transforming the y dimension into a transversal movement. The following picture is an early version of an enlarged head prototype showing the basic principle used.

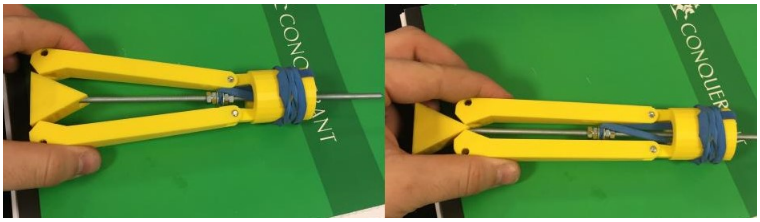

Figure 4. Picture of enlarged example of the tool head

A rod installed through the tube carries this movement to a digital indicator installed on a table. This table moves along the x axis, controlled by a threaded rod. Its position is measured by a meter long digital calliper. Both the calliper and the indicator have a data output, they are automatically synchronised and are able to efficiently record both (x,y) data every 0,7s. We are able to take specific measurements, such as the sides of every tone holes. We are also able to take measurements on two axis of the bore by rotating the bassoon's piece by 90°in cases there are indication of local modifications or warping in the bore where it could have a slightly oval shape.

Before starting the measurements, the comparator will required to be zeroed while the tool head is fitted in an industrial calibration cylinder. The diameter of the cylinder will need to be set as an offset. The calliper's offset will be the value displayed at the first recorded diameter by the comparator at contact with the instrument's bore. The operation has to be as steady as possible since any shock may cause both measuring tools to require recalibration.

3.2.4 Impedance captor

We will use the *Centre de Transfert de Technologie du Mans* (CTTM) impedance captor.

Figure 5. Picture of impedance captor's installation

It is imperative to have a proper connexion without leaks. The swipe configuration we use starts at 20Hz and goes up to 6000Hz, split 5 sections with 3 repeats each. The readings are taken with every notes, covering the whole register. A normalized fingering chart was chosen to represent the most commonly used fingerings. We will then be able to compare the measured and calculated impedance.

3.2.5 Description

We will collect information of the perception of the owners of these bassoons. We expect varied results on this subject, therefore will need to take a psychoacoustic approach. We will hand out a survey enquiring on the perceived sound of their instrument. This survey will describe two major axis of description of the sound often referred by the bassoon community, which are the brightness and the projection. The brightness should appear as a variation proportion of amplitude of harmonic partials. The projection refers to the capacity to maintain a controlled sound while altering the loudness. Since the bassoon shown a large difference of timber in its scale, we will direct the question to compare the instrument with other models of bassoon (of the same maker when possible).

4 Results

4.1 Impedance comparison

The figure bellow compared a measured impedance curve calculated by the wind version of the *Plateforme d'aide à la facture instrumentale* (PAFI) hosted by the ITEMM and a measured impedance. The F2 is the only fingerless fingering on the bassoon. There are significant similarities under 2000Hz.

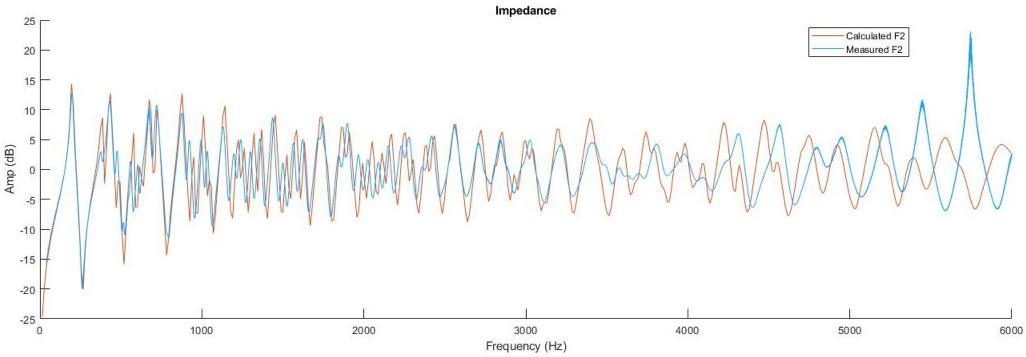

Figure 6. Comparison of Calculated and Measured Impedance of a F2

Although, notes sharing the same register key and oscillation regime (non for the low register) follows almost an exact curve above the 2000Hz, with the exception of the forked E♭2.

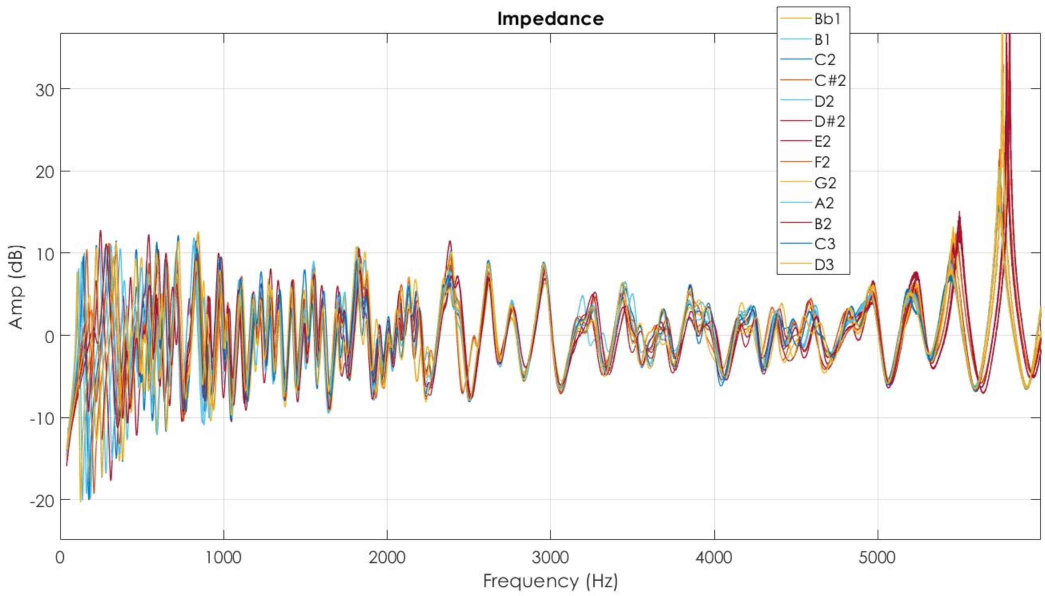

Figure 7. Comparison of Calculated and Measured Impedance of a F2

4.2 Sound analysis

With the use of the recordings acquired with the artificial mouth, we were able to calculate the fundamental frequency, then find harmonic partial peaks and calculate its spectral gravity center. We find that from the middle F3 (opened fingerings) to the lowest note, that the SGC gets considerably higher, well above the 18th harmonic partial for the low B1. It is also important to notice the inconsistency. C#3 being low does correspond to a poor tone fingering, where the G#2 is usually brighter and require adjustment.

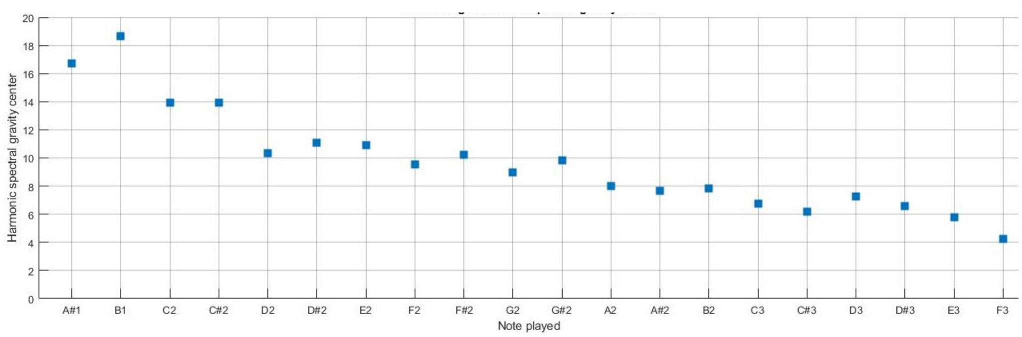

Figure 8. Low register harmonic spectral gravity center

5 CONCLUSIONS

While the development of the measuring tools have been successfully adopted and tested, there are still a number of testing left to do. Mainly, we require much more information on the acceptable range of each protocol in order to assure repeatability. In order to achieve this, the next step is put a pilot project that will take 10 participants and will focus on securing any loose ends left.

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References

[1] Kergomard, J.; Heinrich, J.M. Le basson, histoire, acoustique, l'anche. Bulletin du groupe d'acoustique musicale, 82-83, 1976, 107.

[2] Castellango, M. Écoute musicale et acoustique, Eyrolles, Paris (France), 1st edition, 2015.

[3] Langwill, L.G. The Bassoon and Contrabassoon, Ernest Benn Limited, Toronto (Canada), 1st edition, 1965.

[4] Kopp, J.B. The Bassoon, Yale University Press, Cornwall (England), 1st edition, 2012.

[5] Neverdeen, C.J. Acoustical aspects of woodwind instruments, Northern Illinois University Press, Dekald (U.S.A.), revised edition, 1969.

[6] Chaigne, A.; Kergomard, J. Acoustique des instruments de musique, Belin, Paris (France), 1st edition, 2008.

[7] Campbell, M.; Greated, C. The Musician's Guide to Acoustics, Oxford University Press, New York (U.S.A.), reprinted edition, 2001.