Controllable pitch-bending effects in the accordion playing

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The accordion employs reeds in which the tongue is mounted outside the reed frame in such a way that sounding is normally possible only on one direction of airflow. Under normal operating conditions the reeds behave as blown-closed. Pitch bending technique allows players to make a controllable glide, non tempered glissando, from one pitch to another. Pitch-bending frequency shift, defined as the percentage of the ratio of the frequency change and the original frequency has been measured in a series of experiments. Some of the results involving the dependence of the function on pitch, direction of the bellows movement, cassotto possibilities and harmonic number are reported here. If the player qualifies, he/she can make controllable pitch-bending effects where the glissando may fall an exact semitone.

1 Introduction

The term Accordion is the proper generic term for all members of a complex family of free-reed hand-held aerophones. They are made to sound by buzzing a thin steel tongue, which is attached to one side of a metal plate containing an aperture through which the reed tongue can actually pass, that is, they utilize the free reed principle. The reeds are powered by bellows and normally controlled by means of two keyboards.

A modern concert accordion consists of two independent manuals joined by the bellows, which power the reeds. The air of the bellows is driven only through those reeds whose corresponding valves (or shoes) are lifted when any button of any manual is acted. The reeds of each manual are laid out in different sets of independent reeds, combined by the registers. Each manual gives almost the tessitura of a grand piano.

The sound generators of the accordion are the free reeds stimulated by the airflow supplied by the bellows. Each free reed is riveted on a metal plate containing an aperture through which the reed tongue can actually pass. The not riveted end of the reed is free to vibrate from one side and the other of a slot carved on the metal plate under the reed. To enable the vibration of the reed, there must be a good adjustment between the slot on the plate and the reed [1]. Figure 1 shows the usual action of an accordion free reed. This reed is an inward-striking reed [2], it only vibrates when the air comes from the same side of the plate on which the reed is riveted.

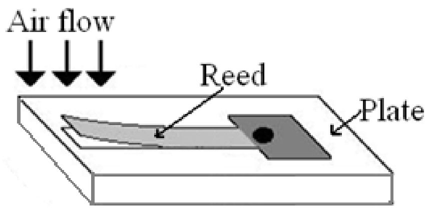

Fig.1 An accordion free reed placed on its plate.

On the other side of the metal plate there is another equal reed with its corresponding slot. One of the reeds oscillates when opening the bellows, the other when closing. The concert accordions are chromatic, that is the two reeds emit the same sound, and any button will give the same note regardless of the direction of the bellows.

In the case of big or medium reeds, the opposite side of the slot is completely covered by a strip made of leather or plastic that moderates the airflow and avoids air passage through the hole of the reed tongue that it is not activated. All the reeds up to G4 have their corresponding strip of leather on the opposite side of the plate. From G#4 to C6 they have a strip of plastic. From that note up to C#8, the highest note, there is no strip.

Although the free reed is characterized by the stability of the frequency when the pressure is varied within certain limits [3] and the accordion is tuned to emit fix equal-tempered notes [4] there are special techniques of playing that imply a continuous descend of the frequency. This "pitch bending" or non tempered glissando effect is well known by accordion players, and it has also been studied in some free-reed instruments [5, 6, 7, 8].

In this work, a set of experiments have been carried out in order to characterize the pitch-bending effect. The frequency change, the primary objective of the musician when pitch bending is performed, is accompanied by loudness change, different for each harmonic of the note. The final sound is perceived softer than the original one, and also with a different timbre.

Frequency and sound level pressure shift functions have been defined. The experimental results show the dependence of these functions on pitch, direction of the bellows movement, cassotto possibilities and harmonic number. These results are compared with those reported by accordion performance literature [9, 10, 11] and some surveys of luthiers and accordion players [4].

2 Background

The pitch bending effect was first used by Norwegian composer Per Nørgård in his work "Anatomic Safari", for solo accordion, in 1967. It was also used in "De profundis" (1978), for solo accordion, by Russian composer Sofia Gubaidulina, who made it popular among accordionist and composers, and many other composers for concert accordion all around the world.

In the most common way to make a pitch bending the player slightly presses down the button (so the valve is maintained semi-opened) while, with the left arm, he/she increases the tension on the bellows. Then the button is lifted up gradually.

According to literature, these are the characteristics of the pitch bending performed on the accordion:

- There is no way to force a pitch sharp.
- The sound level decreases as a pitch is bent flat.
- The 8-foot (with or without cassotto) or 16-foot registers of the right hand manual are best conducive to pitch bending. They are more comfortable, because the right hand can be leaned on the edge of the right keyboard while the left hand remains free to control the bellows.
- The glissando may fall an exact semitone approximately.

3 Experiments

In this work a Pigini, Sirius model, concert accordion [12] has been used. It consists in two manuals, the right and the left ones. The right manual consists of buttons arranged chromatically, each button giving a single note. In the right manual there exist four independent sets of reeds: two central reeds (8-foot reed), a low one (16-foot, sounding an octave below the 8-foot) and a high one (4-foot, sounding an octave higher than the 8-foot), which can be mixed by means of the registers, giving a total of 15 different combinations. The notation in "foot" is taken from the registration of the organ.

Both the reed of 16-foot and one of the 8-foot are laid out inside a special chamber, called "cassotto". The cassotto makes the sound emitted by the inner reeds to be warmer than the sound of the outer reeds, because the cassotto works as a filter that attenuates the higher harmonics. For frequencies higher than 6000 Hz, our measurements show that this attenuation is around 30% in sound pressure level.

The left free bass manual consists of three independent registers distributed as 8-foot, 4-foot and 2-foot.

The dynamics of the sound has been controlled measuring the sound intensity with an "Extech Instruments 407727" sound meter level placed 50 cm in front of the accordion. An experienced player has been instructed to play an original mezzo forte sound and the pitch bending effect. The mezzo forte dynamics corresponds to about 70 dBA in the sound meter level.

The sounds have been recorded with a Pre-polarized Free-Field ½" Microphone Type 4189-A21 by Bruel&Kjaer, placed at about 50 cm in front of the accordion. Frequency domain and time domain data have been obtained using PULSE Bruel&Kjaer software.

In the frequency domain FFT spectra of 3200 lines till 10 kHz have been obtained. In the time domain, the measurements have been carried out every 25ms, completing a total measurement time of ten seconds.

Each note has been measured five times. Each time, the original and the final sounds have been recorded. The final sound has been taken ten seconds later (when pitch bending has been achieved) than the original sound. The frequencies of the ten first harmonics of the note and their sound pressure levels have been determined. All the results are the mean values of the five measurements.

The following notes of the right manual have been studied. These pitches have been chosen according to most referenced sounds of the accordionist literature:

- All the notes from E1 to E3 for the 16-foot register.
- All the notes from E2 to E3 for the 8-foot register inside cassotto.
- All the notes from E2 to E3 for the 8-foot register out of cassotto.

All these notes have been studied varying the direction of the movement of the bellows (opening and closing), the influence of the cassotto (inside cassotto, out of cassotto) and the harmonic number of the note.

4 Results

For each note, the frequency of the original sound is denoted as f_{or}, and the frequency of the final sound, ten seconds later when the pitch bending has been produced, is denoted as f_{fin}. The frequency shift function has been defined as:

$$frequency\,shift\,(\%) = 100\left[\frac{f_{or} - f_{fin}}{f_{or}}\right] \quad (1)$$

It represents the ratio of the difference between both frequencies to the original one, expressed as a percentage. For each note, the frequency shift of the first ten harmonics has been measured and the mean value has been calculated.

Similarly, the sound pressure level of the original sound is denoted as Lp_{or}, and the sound pressure level of the final sound, ten seconds later, when the pitch bending has been produced, is denoted as Lp_{fin}. The sound pressure level shift function is defined as:

$$Lp\,shift\,(\%) = 100\left[\frac{Lp_{or} - Lp_{fin}}{Lp_{or}}\right] \quad (2)$$

It represents the ratio of the difference between both sound pressure levels to the original one, expressed as a percentage. For each harmonic the mean value of all the notes of an octave has been calculated.

4.1 Frequency shift

The dependence of the mean value of the frequency shift on the pitch is shown in figures 3, 4 and 5 for the 16-foot register (inside cassotto); 8-foot register (inside cassotto) and 8-foot register (out of cassotto) respectively. All the notes were recorded and analyzed as described in the previous section.

From these results it can be concluded that there are no significant differences of the frequency shift between the registers and the notes.

All the notes have frequency shifts varying between 1% and 8%, so the final pitch can be between $0.99f_{or}$ and $0.92f_{or}$, that is the maximum change is of the order of a semitone.

Figures 2, 3 and 4 were taken on different movements of the bellows (opening and closing). There is a slightly increase in the frequency shift when the bellows are closed. Even though these results suggest that the frequency shift increases with the closing movement, this conclusion may be attributed to a natural physiological factor: closing the arms seems to be less energetic and more controllable than opening them.

The dependence of the frequency shift on the pitch for the 8-foot register (inside cassotto) and 8-foot register (out of cassotto) is shown in figures 5 (opening bellows) and 6 (closing bellows).

As it would be expected, the cassotto does not affect the frequency values. As in the previous results of the Fig. 2, 3 and 4, the slightly differences of the frequency shift are related to the movement of the bellows. The cassotto does not act on the sound generators (the reeds) and it only works as an attenuator of the higher harmonics of the emitted sound.

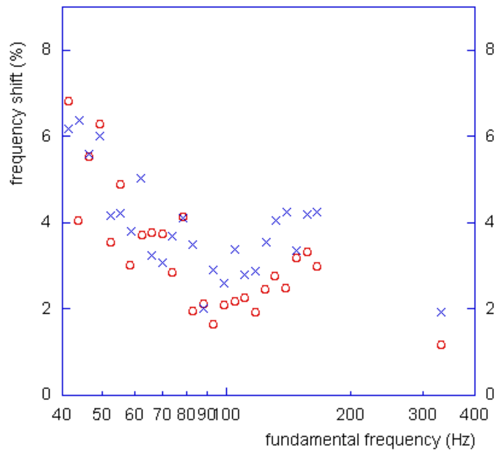

Fig.2 Frequency shift function versus fundamental frequency for the notes of the 16-foot register (inside cassotto). Circles correspond to the notes obtained opening the bellows and crosses to that obtained closing them. The maximum frequency shift error is 2%.

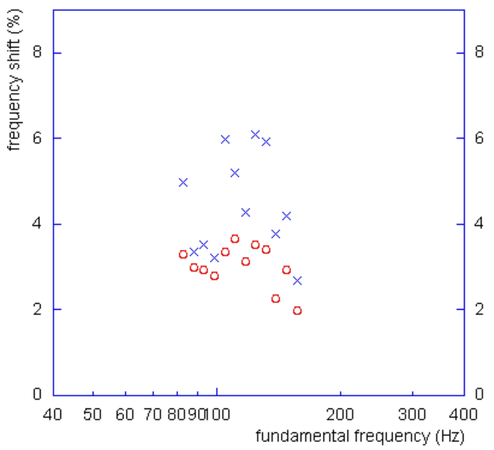

Fig.3 Frequency shift function versus fundamental frequency for the notes of the 8-foot register (inside cassotto). Circles correspond to the notes obtained opening the bellows and crosses to that obtained closing them. The maximum frequency shift error is 1.5%.

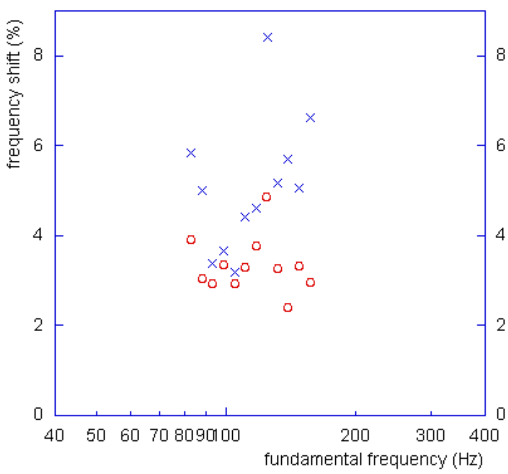

Fig.4 Frequency shift function versus fundamental frequency for the notes of the 8-foot register (out of cassotto). Circles correspond to the notes obtained opening the bellows and crosses to that obtained closing them. The maximum frequency shift error is 2%.

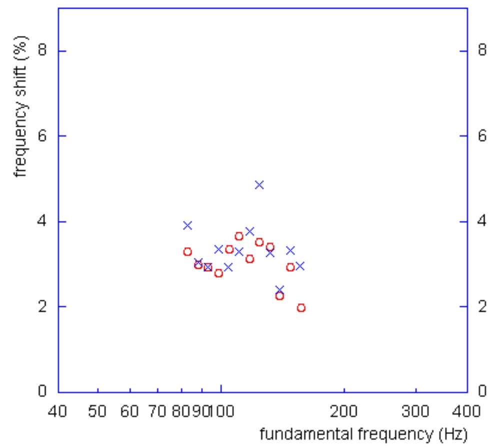

Fig.5 Frequency shift function versus fundamental frequency for the notes of the 8-foot register. Circles correspond to the notes obtained inside cassotto and crosses to that obtained out of cassotto. All the measurements have been made opening the bellows. The maximum frequency shift error is 1%.

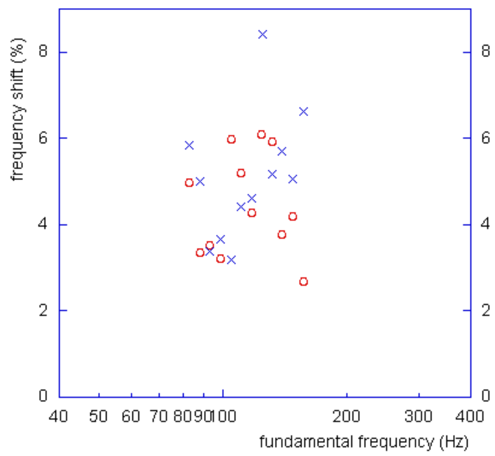

Fig.6 Frequency shift function versus fundamental frequency for the notes of the 8-foot register. Circles correspond to the notes obtained inside cassotto and crosses to that obtained out of cassotto. All the measurements have been made closing the bellows. The maximum frequency shift error is 1%.

The harmonicity [13] of the bended note is approximately maintained as far as the first ten harmonics are concerned. All the ten harmonics of each note give very similar values of the frequency shift. For this reason we have defined the frequency shift function as the mean value of the relative frequency shifts of the ten harmonics.

4.2 Sound pressure level shift

Figure 7 shows the mean values of the sound pressure level of the first ten harmonics of the F2 note of the 8-foot register out of cassotto.

The loudness of the final sound is lower than that of the original one, and this effect is different for the different harmonics. Besides, it can be seen that the variability of the sound pressure level is greater for the final state than for the original one. This result is related with the physical difficulty to perform the pitch bending, and the musician feels a sensation of instability in the achievement of the final frequency.

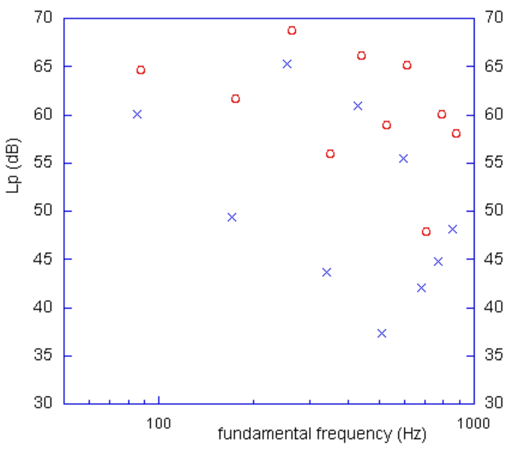

Fig.7 Sound pressure levels versus fundamental frequency for the first ten harmonics of the F2 note of the 8-foot register out of cassotto, opening the bellows. Circles correspond to the harmonics of the original sound and crosses to those of the final (pitch bended) sound. The maximum Lp error is 2dB.

For the pitch bended note, the loudness changes were on average 15% greater than those measured without pitch bending (5%). Although the player has increased the pressure exerted on the bellows, the pressure level has diminished. This result seems to be related with the fingering control of the airflow.

The dependence of the mean value of the sound level shift on the pitch is shown in figures 8, 9 and 10 for the 16-foot register (inside cassotto); 8-foot register (inside cassotto) and 8-foot register (out of cassotto) respectively. All the harmonics were recorded and analyzed as described in section 4. The even harmonics suffer a greater decrease of the sound pressure level than the odd harmonics. This could be related to the change of the resonance chamber of the metal plate. When the valve is almost closed, the chamber changes its configuration from an open-open pipe to an open-close one, with the consequent decrease of the amplitude of the even harmonics.

Since the frequency of the final note is very near to the original one, the cassotto does not affect very much the sound level (see Fig. 11).

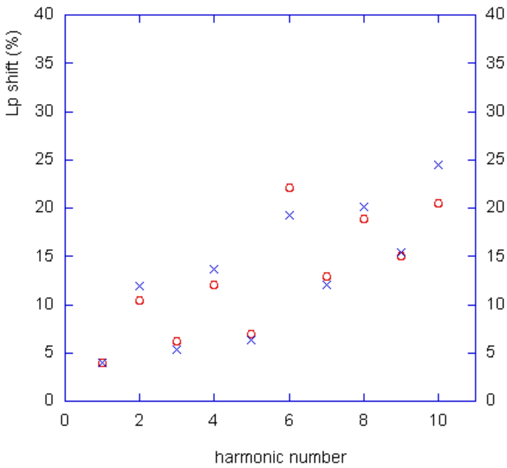

Fig.8 Sound pressure level shift function versus harmonic number for the notes of the 16-foot register (inside cassotto). Circles correspond to the notes obtained opening the bellows and crosses to that obtained closing them. The maximum Lp shift error is 1%.

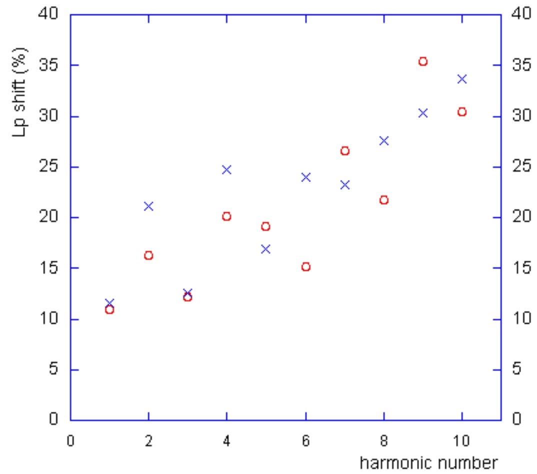

Fig.9 Sound pressure level shift function versus harmonic number for the notes of the 8-foot register (inside cassotto). Circles correspond to the notes obtained opening the bellows and crosses to that obtained closing them. The maximum Lp shift error is 1%.

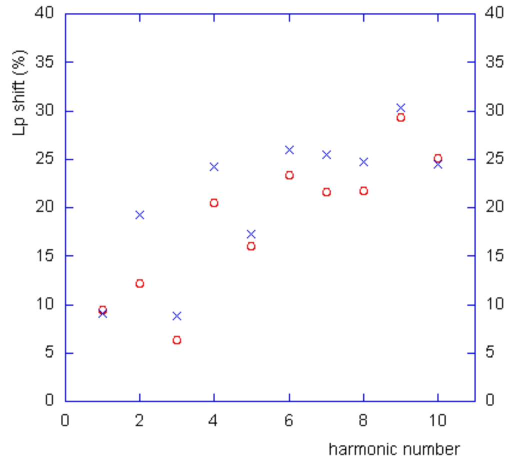

Fig.10 Sound pressure level shift function versus harmonic number for the 8-foot register out of cassotto. Circles correspond to the notes obtained opening the bellows and crosses to that obtained closing them. The maximum Lp shift error is 1%.

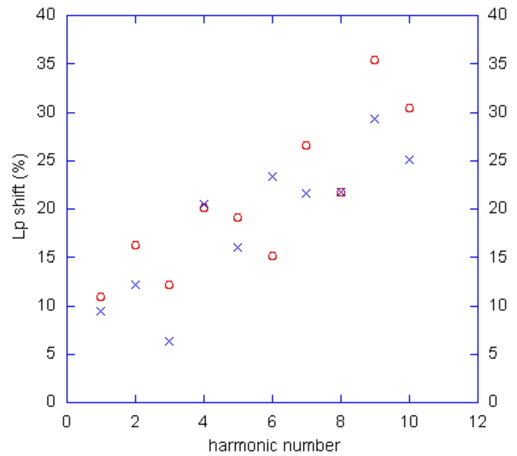

Fig.11 Sound pressure level shift function versus harmonic number for the 8-foot register inside and out of cassotto, opening the bellows. Circles correspond to the register inside cassotto and crosses to the one outside of cassotto. The maximum Lp shift error is 1%.

5 Conclusions

The pitch bending effect has been characterized for the right manual of a concert accordion. The pitch bending of a note results in a frequency flat accompanied by a loudness decrease.

For the frequency variation, results show that there are no significant differences of the frequency shift along the studied tessitura, the maximum change being about a semitone. There is a slightly increase in the frequency shift when the bellows are closed, although this effect could be attributed to the musician's physiological ability to control the movement of the bellows, since closing the arms is easier than opening them. The cassotto does not affect the frequency change and it only works as a filter that attenuates the higher harmonics of the emitted sound, without directly acting on the reeds. All the ten first harmonics of each note give very similar values of the frequency shift, so the harmonicity of the bended note is approximately maintained.

The loudness variation is less for the original sound than for the final one and this effect is different for the different harmonics: even harmonics suffer a greater decrease of this parameter than odd harmonics. The variability of the sound pressure level is greater for the final state than for the original one, due to the physical difficulty to perform the pitch bending.

It has been impossible to carry out the pitch bending with pitches from C6 to C#8, the reeds without strip. Furthermore, no one of these reeds could be drowned, no matter the dynamics or the hardness of the attack. For these reeds, while the player increases the tension of the bellows, the absence of the strip leaks the airflow through the slot of the metal plate.

Acknowledgments

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