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Pitch bending and multiple-mode reed vibration in mechanically-blown free reed instruments

James P. Cottingham

Coe College, Cedar Rapids, Iowa 52402 USA

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ABSTRACT

Pitch bending in the harmonica, in which manipulation of vocal tract resonances plays an essential role, has long been a common practice. Pitch bending in free reed instruments with mechanically driven air supplies, such as the reed organ, harmonium and accordion, is a different matter. At least two methods of pitch bending in the accordion have been studied and demonstrated. The first, likely to be musically useful only in limited circumstances, involves partial opening of the pallet valve combined with variations in blowing pressure. The second, recently described and implemented in the accordion by Tonon [Thomas Tonon, J. Acoust. Soc. Am. 126: 2217 (2009)], involves modifying the construction of the instrument to include a resonating chamber in addition to the standard reed chamber. Accordions implementing this pitch bending mechanism are currently being used by some professional players, notably Kenny Kotwitz. Another case of interest is that of a free reed coupled to a pipe resonator. It has been established that, in certain cases, the vibrational frequency of the reed and the sounding frequency of the reed-pipe will approximate a resonant frequency of the pipe. A somewhat different case is considered here. It is shown that, if a free-reed pipe is constructed with a pipe resonator that provides a suitable mismatch in frequencies with the fundamental frequency of the reed, it is possible to obtain a reed-pipe combination in which the mechanically blown reed vibrates in the second transverse mode and the reed pipe sounds at this frequency. Furthermore, for some combinations of pipe length and blowing pressure, it is possible to produce multiphonics in which two, or occasionally three, frequencies are sounded simultaneously that are the frequencies of transverse modes of the reed rather than pipe mode frequencies. The musical possibilities of these reed-pipes have yet to be explored.

INTRODUCTION

Pitch bending by harmonica players is a standard practice for all skilled players, and is a requirement for certain musical styles. This pitch bending exploits the coupling of reed vibration to the vocal tract resonances of the player as well as coupling between the two reeds, one for each direction of airflow, that share a single reed chamber. Significant acoustical studies of pitch bending in the harmonica have been published by Johnston, Millot, and Bahnson et. al. [1-3]

This paper concentrates on the possibilities for player-controlled pitch bending in instruments such as the accordion, in which resonances of the vocal tract are not an available resource for the player. Two methods of pitch bending in the accordion are discussed. In the first, using a standard accordion, the player can bend the pitch downward with a combination of increased pressure and a partially opened pallet valve. [4-5] The second involves modifying the accordion to include an additional resonating chamber. [6] The first method, which has sometimes been employed by composers and players, seems useful mainly as an occasional special effect. The modified pitch-bending accordion, on the other hand, gives the player a flexibility similar to, but not identical with, the pitch bending possibilities available to the player on the harmonica.

In approaching the principles of design of the pitch-bending accordion, some interesting results involving the free reed coupled to a resonator are explored.

PITCH BENDING TECHNIQUE WITH THE UNMODIFIED ACCORDION

Pitch bending by the player on an unmodified accordion

Llanos-Vazquez and co-workers recently reported results of experimental measurements made on pitch bending techniques used by players on standard accordions. [4] In particular, it was shown that a pitch can be bent downward as much as a semitone by simultaneously using the bellows to increase the pressure and partially closing the pallet valve by depressing the key or button only part way.

Laboratory results on the possibilities for pitch bending

Coyle, et al., recently conducted some laboratory experiments on pitch bending. [5] These explored effects of changes in bellows pressure, partial opening of the pallet valve, and reducing the volume of the reed chamber by means of small inserts. In these experiments the accordion bellows were replaced by a clear acrylic chamber of appropriate volume, making it possible to observe reed vibration with a laser vibrometer. A small organ blower was used for the air supply.

Some of the results are summarized in Figures 1-3. Figure 1 shows the sounding frequency of a typical accordion reed as a function of blowing pressure. The trend shown is typical of that reported for similar free reeds in numerous previous studies. In the example shown, the rather modest drop in frequency is around 0.7 percent.

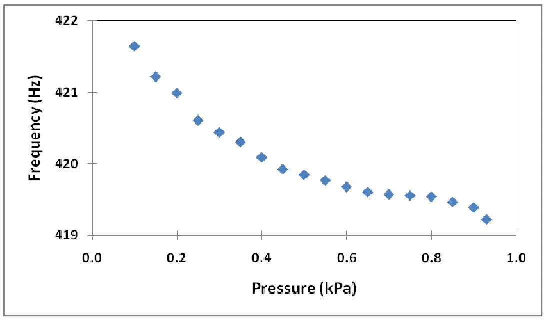

Figure 1. Sounding frequency of an accordion reed as a function of blowing pressure

The sounding frequency can also be altered by using the key or button to vary the pallet opening. Figure 2 shows the sounding frequency as a function of pressure for three different positions of the pallet. It can be seen that, at high blowing pressure, the frequency can be reduced by over 2 percent by this means. It is not clear how easily this could be implemented by a player in typical musical performance.

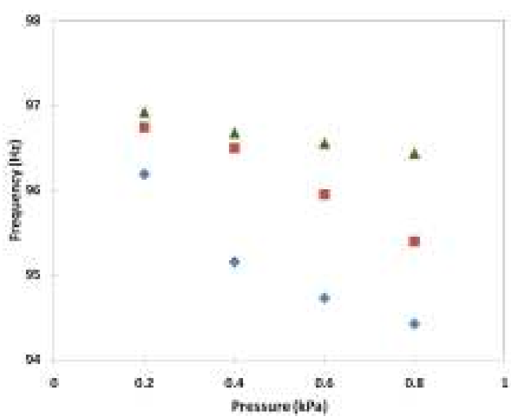

Figure 2. Sounding frequency of an accordion reed as a function of blowing pressure for the pallet valve fully open (top set of data), open about 50% (middle), and open about 25% (lower data set)

The experimental results show that reducing the interior volume of the reed chamber by inserting small wooden wedges can lower the pitch by a fairly substantial amount, as much as 2.5% for the example shown in Figure 3. If this is combined with partial opening of the pallet, the pitch change can be increased substantially. These results are generally consistent with the possibilities reported by Llano-Vazquez, et al., but would seem to have rather limited usefulness if the goal is a flexible, generally applicable method of pitch bending for the accordion.

Before looking at a more sophisticated, flexible method for pitch bending in the accordion, we can first consider a system consisting of a free reed coupled to a pipe resonator. A considerable amount of experimental data is available for such systems.

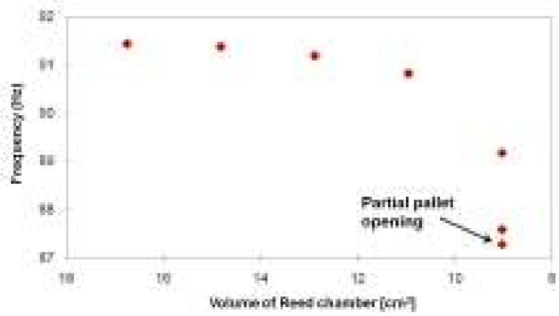

Figure 3. Sounding frequency of a reed as a function of reed chamber volume

SOUNDING FREQUENCY OF A FREE REED COUPLED TO A PIPE RESONATOR

Description of the reed-pipes

The reed-pipe system in question consists of a reed from an American reed organ (similar in construction to an accordion reed) coupled to lengths of 1.5 cm diameter PVC pipe. A wide range of lengths have been studied. The organ reed is attached to a rectangular hole in the side of the pipe with the reed tongue pointing toward the longer length of pipe.

Figure 4. A harmonium type reed from an American reed organ coupled to a cylindrical pipe resonator

Vines et al. gathered a considerable body of data on such systems. [6] Sounding frequencies of the reed-pipe were obtained over a wide range of blowing pressure for each pipe length, and the resonant frequencies of the pipes were obtained from pipe impedance curves.

Variation of playing frequency with length

A sample from more recent data using a 646 Hz organ reed with various pipe lengths is presented in Figure 5. The most obvious trend in the data is that the sounding frequency generally tends to be just below a pipe resonance or, if no pipe resonance is close enough to the natural frequency of the reed, the sounding frequency is near the reed frequency.

In addition to this "normal" behaviour, some unusual phenomena are possible if there is a mismatch between the natural frequency of the reed and the pipe resonances. These are illustrated here using the case of the 646 Hz reed coupled with a 47-cm length of pipe.

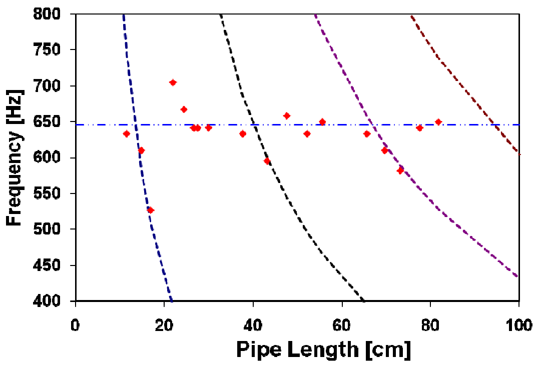

Figure 5. Variation of sounding frequency with pipe length for the free reed-pipe. The horizontal line is the reed frequency; the curved lines are the pipe resonance frequencies

Reed-pipe sounding in higher transverse modes

With an appropriate mismatch of the fundamental pipe resonance frequency and the frequency of the first transverse mode of the reed, the free-reed pipe can be made to sound at the frequencies of the second or third transverse modes of the reed, and occasionally at two of these simultaneously. Figure 6 shows a spectrogram of vibration of a 646 Hz reed coupled to a 47-cm pipe as the blowing pressure is gradually increased.

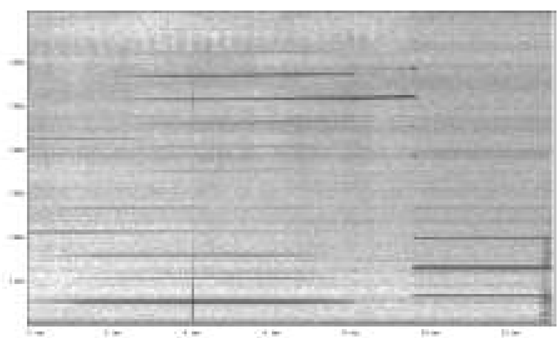

Figure 6. Spectrogram showing vibrational spectrum of a 646 Hz reed in a 47-cm pipe with increasing pressure

It can be seen (and heard) that, as the blowing pressure increases, the reed pipe sounds (faintly) in mode 2, then sounds in modes 1 and 2 simultaneously, followed by modes 1 and 3 together and eventually mode 3 alone. At even higher pressure the reed sounds in mode 1 alone

THE PITCH-BENDING ACCORDION

Principles of operation

In 1997 Thomas Tonon patented a mechanism that allows flexible pitch bending in keyed free-reed instruments (US Patent 5824927; International WO/1977/044777). The mechanism works on the same principle involved in pitch bending using a pipe discussed in the previous section. [7-8]

In free reed instruments such as accordions and concertinas, the reeds are mounted over reed-chamber cavities that generally affect the timbre, but usually have little effect on the frequency of vibration of the reed, since resonances between the reed and cavity are rare. In the Tonon design the cavity is intentionally designed for near resonance with the reed, and a mechanism is provided that permits the musician to engage the resonance by changes in key pressure.

Figure 7, from Tonon's patent description, shows a typical accordion mechanism with dual sets of reeds (15, 17), one set for each direction of airflow, as well as the pallet (25) and the reed chamber cavities (27, 28). Figure 8 shows the modifications introduced for pitch bending, including a tube-like cavity (opening at 91) and a valve (93) kept open with a spring (99). With sufficient key pressure by the player, this valve is forced to close and the reed becomes coupled with the resonating tube, lowering the sounding frequency. This can be done smoothly under the control of the player, allowing a controlled pitch bend.

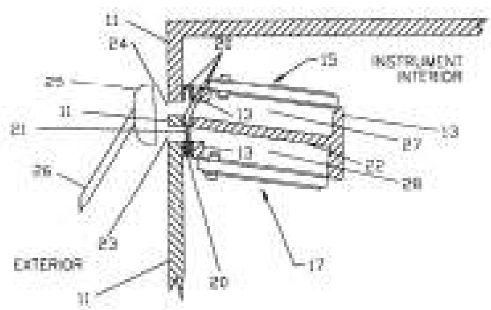

Figure 7. Diagram of standard accordion mechanism from the Thomas Tonon patent description [9]

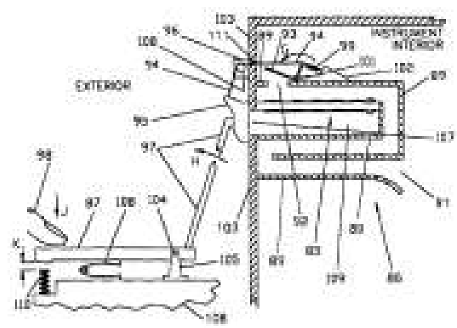

Figure 8. Diagram of accordion pitch bending mechanism from Thomas Tonon patent description [9]

Musical examples

More detailed discussion of the design of the pitch-bending accordion as well as a number of musical examples and other information can be found at http://www.bluesbox.biz.

One such example is given below, an excerpt of "One for My Baby" played by accordionist Kenny Kotwitz on a pitch bending accordion of the design discussed here. Although there is some subtle pitch bending is several places in this example, the most obvious use of the pitch bending capability can be seen near the 8-second mark.

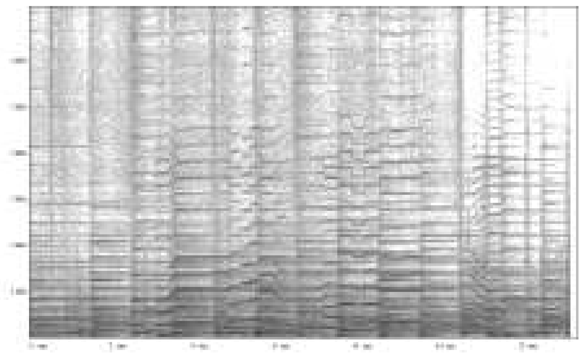

Figure 9. Excerpt from "One for my Baby" played by Kenny Kotwitz on an accordion with a pitch-bending mechanism

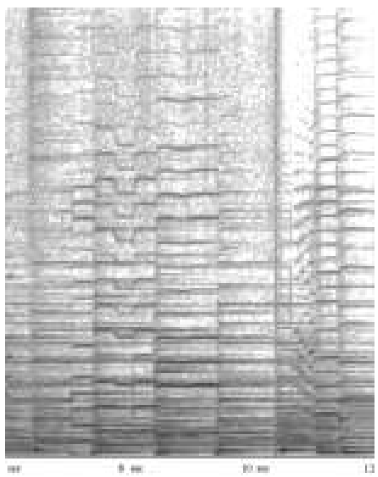

Figure 10. Closer view of the pitch bending in Figure 9

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