THE ASIAN FREE REED MOUTH ORGANS

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Abstract

Mouth-blown instruments using a free reed coupled to a pipe resonator have a long history in China, Japan, and throughout Southeast Asia. The sheng employs a free reed at one end of a closed tube with a conical-cylindrical cross section. The khaen employs an open tube of effective length L, with the reed located at approximately L/4. The bawu is a closed cylindrical pipe with the free reed at one end, in which the effective acoustical length is varied by the use of tone holes. The playing frequency of each pipe of the sheng or the khaen is typically slightly above both the resonant frequency of the pipe and the natural frequency of the reed. In the bawu, on the other hand, both the pipe resonance and sounding frequency are normally well above the natural reed frequency, resulting in a striking difference in tone quality. Experimental studies have been made of the sheng, khaen, and bawu as well as simulated instrument tubes constructed from PVC pipe. Acoustical measurements made include studies of reed vibration using a laser vibrometer system, measurements of sound spectra produced when the pipes are played, and impedance measurements of the pipes. Comparisons have been made with theoretical work on the coupling of the reed vibration with the pipe resonator. The results are generally consistent with both experimental results from earlier studies and with theoretical considerations regarding reed-pipe coupling.

INTRODUCTION

Unlike the free reeds found in Western instruments such as the reed organ, accordion, and harmonica, the reeds of the Asian free reed mouth organs are not only coupled to pipe resonators, but are approximately symmetric, so that the same reed can operate on both vacuum and pressure (inhaling and exhaling). Figure 1 shows typical reeds from a sheng and an American reed organ. The *sheng*, *sho*, and *khaen* all employ one reed per pipe, thus requiring a separate pipe for each pitch. Also common in various parts of South and Southeast Asia are free reed pipes which allow change of pitch using finger holes. One version of this type of instrument now common in China is the *bawu*. Details on these instruments are available in the article by Miller [2].

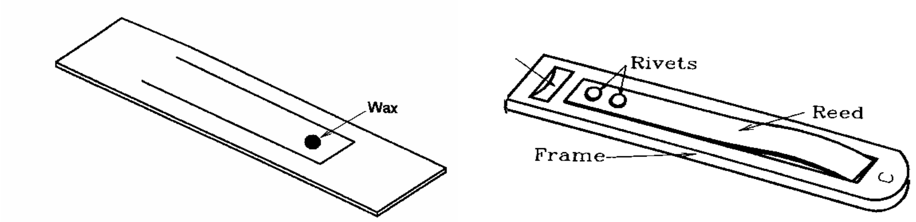

FIGURE 1. Reeds from a sheng (left) and an American reed organ (right) from Gellerman [1].

The free reeds used in the Asian mouth organs are cut from a single piece of thin metal, typically brass or a bronze alloy, and set into a bamboo pipe. In the single note per pipe instruments, a finger hole is drilled at a point that destroys the pipe resonance and prevents the reed from sounding unless the hole is closed. Wind is provided by blowing either in or out through the mouthpiece which forms the opening of the air chamber that surrounds the reeds. The instrument is held upright with the air chamber supported by the hands. Fingers and thumbs of both hands are available to close the holes and sound notes. It is typical in playing the instruments that several notes are sounded simultaneously, some of them serving as drones. See References 2 and 3 for more detailed information.

The frequency of reed vibration is determined by both the reed and the pipe. One or two tuning slots (usually two for the khaen) are cut into the back of the pipe, determining the effective acoustical length. The vibrating frequency of the blown reed can within certain limits be pulled to match the pipe resonance, so that fine tuning is done by means of the position of the tuning slots. In the khaen, reed length only approximately corresponds to sounding frequency, with pipe length apparently used as the prime means for tuning. Measurements taken on a sheng, on the other hand, indicate that the individual reeds are much more carefully tuned to match the pipe resonance [4].

A characteristic shared by the Asian free reed mouth organs with other free reed instruments is that the sounding frequency drops as blowing pressure is increased. Data on this has been reported elsewhere [3,4]. The pitch change encountered in practice does not generally seem to cause musical problems.

IMPEDANCE CURVES

Impedance curves have been measured for the bawu, the khaen, and the sheng following the method of Benade and Ibisi [5]. For khaen pipe impedance measurements, the pipes used were constructed from PVC tubing with dimensions similar to actual khaen pipes. For the sheng, bamboo pipes from a real instrument were used. In the case of the bawu, measurements were made on a "bawu" constructed from a piece of PVC pipe with a bawu reed attached as well as on actual instruments. A few results for the khaen and sheng are given below. Impedance curves for the bawu have been reported elsewhere [4]. The impedance curve measurements for the PVC khaen pipes, of which two are shown in Figure 2, are apparently the first such measurements on khaen pipes.

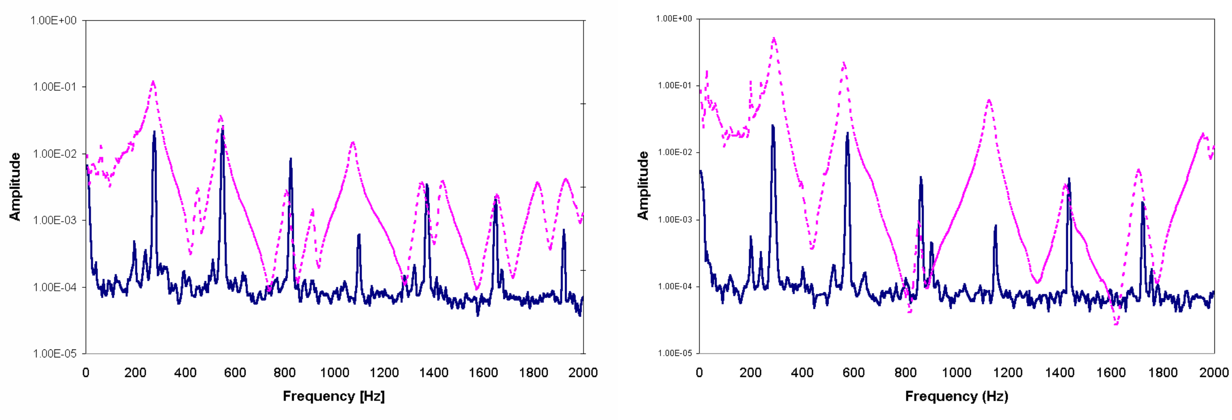

FIGURE 2. Impedance curves (dashed) and sound spectra (solid) of a 59-cm PVC khaen tube: (left) with end sections of lengths 11 cm and 35 cm, (right) with no end sections.

Khaen pipes

The fundamental frequency of the sound spectrum (275 Hz) in Figure 2 is just above the frequency of the first impedance peak (270 Hz), which confirms previous observations that such a free reed pipe will sound at a frequency above the reed frequency and close to a resonant frequency of the pipe. If the length of the tube places the fundamental below the reed frequency, the reed-pipe can sound near the second harmonic of the pipe [3,4]. The difference in tone quality observed in comparing khaen pipes with and without the end sections seems closely related to the differences in the impedance curves for the two cases, as illustrated in the figure.

Sheng pipes

Sheng pipes are cylindrical over most of their length, but the lower portion in which the reed is mounted is conical. The frequencies of the resonances identified by the impedance peaks are not harmonic. The pattern observed for the sheng is that the sounding frequency of the pipe is above that of the first impedance peak, with the second harmonic of the sound spectrum apparently reinforced by the strong nearby peak in the impedance curve.

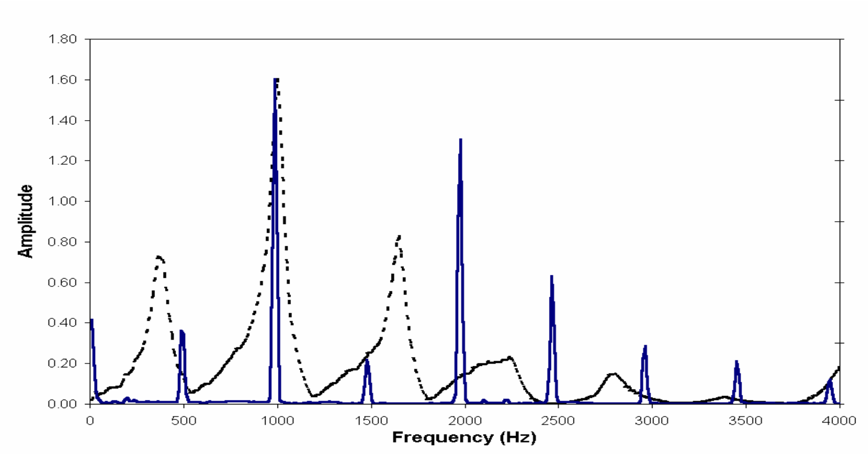

FIGURE 3. Impedance curve (dashed) and sound spectrum (solid) of a sheng pipe.

PLAYING FREQUENCY

Figure 4 shows the general relationship between frequency and pipe length for a khaen pipe. The pipe length was gradually shortened by cutting lengths from the original pipe. As can be seen in the graph, the sounding frequencies follow closely the fundamental pipe frequency, always remaining slightly above it. At the shortest pipe length in this example, the reed did not sound at normal blowing pressure (0.8 kPa), but could be made to sound at +1.7 kPa. At this same length, underblowing (0.3 kPa) caused the reed-pipe to sound at a frequency very close to the reed frequency. The results presented in Figure 4 show that the sounding frequency of the reed-pipe combination is higher than the natural resonance frequencies of either the reed or the pipe taken alone.

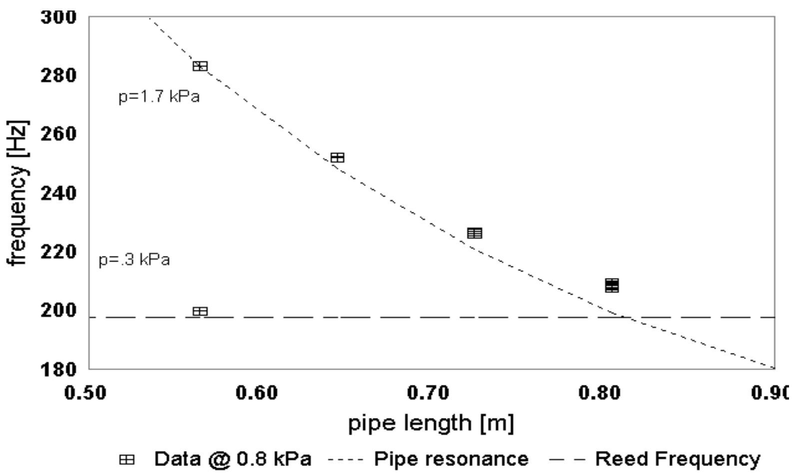

FIGURE 4. Sounding frequency of a khaen tube as a function of length *at 0.8 kPa, except as noted. (Note that this figure is a correction of a result reported earlier in Reference 3.)*

Figure 5 shows the playing frequency of a bawu as a function of pipe resonance frequency The normally blown notes, obtained both manually and mechanically at around 2.0 kPa, are generally close to, but slightly above, the measured impedance frequency of the pipe. Underblown notes are close to the natural frequency of the reed. Notes played so high above the reed frequency have a dramatic difference in tone quality compared to those near the reed frequency.

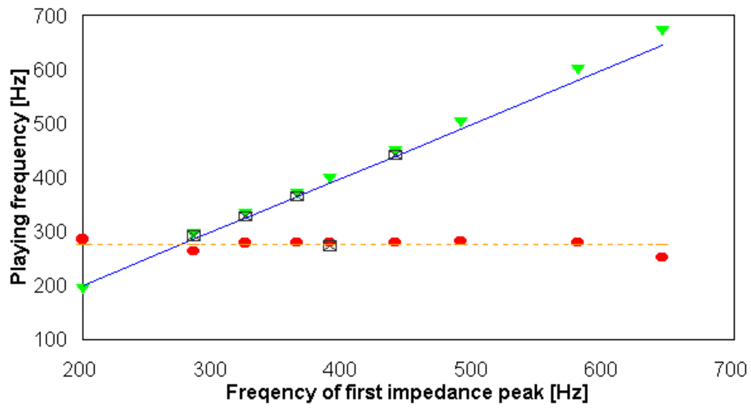

FIGURE 5. Playing frequency of a bawu as a function of pipe resonance frequency. Solid elliptical data points from underblowing are near the reed frequency (horizontal line).

SUMMARY

The free reeds coupled to pipe resonators in the instruments under consideration seem to behave as "opening" or "outward striking" reeds as discussed by Fletcher [6], with the sounding frequency of the reed-pipe combination is above the natural frequencies of both the reed and the pipe. For the bawu, a free reed pipe with finger holes, the sounding frequency can be about an octave above the reed frequency; for the cut-off khaen pipe it can be about half an octave. Previous measurements of reed motion using a laser vibrometer verify that for these instruments the free reed tongue makes only slight excursions in the upstream direction, thus approximating the outward striking reed model [7].

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