

Sound of the HANG

[David Wessel](#), [Andrew Morrison](#), and [Thomas D. Rossing](#)

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5aMUF3. Sound of the HANG

David Wessel, Andrew Morrison* and Thomas D. Rossing

***Corresponding author's address: Department of Physics and Astronomy, Northwestern University, 2145 Sheridan Rd, Evanston, IL 60208, achmorrison@gmail.com**

Previous studies of the HANG [T. D. Rossing, U. Hansen, F. Rohner, and S. Schärer, 142nd ASA meeting, December 2001; T.D.Rossing, A. Morrison, U. Hansen, F. Rohner and S. Schärer, Proceedings of ISMA07, Barcelona, 2007] have discussed the modes of vibration and the sound radiation field of the HANG when note areas are excited by sinusoidal force. Since the HANG is a hand-played steel instrument, a wide variety of playing techniques are used by various performers. We report on the sound of the HANG when played in various ways. Recordings of the HANG were made with a hemispheric microphone array. The instrument was excited by taking multiple samples of each of a number of striking techniques with the hand. These include single strokes from the soft part of the finger, as well as, the finger nail itself. Various grace note techniques like flams were also investigated. Damping was controlled by the time the finger remained in contact with the instrument, as well as, by using the palm. Force hammer measurements were also included. We report on these measurements and incorporate them in to an excited-resonance model of the instrument. Demonstrations of the real and modeled instrument will be provided.

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1 Introduction

The HANG is a hand-played steel instrument. Since its introduction in 2000, over 7000 instruments have been created by PANArt Hangbau AG in Bern, Switzerland. Since it is played with the hands, it is possible to create many different timbres from its notes.

The history of the HANG has been described by its creators, Felix Rohner and Sabina Schärer [1,2]. The way in which the note areas vibrate and produce sound and the way in which the sound is radiated have also been described in several papers [3,4]. In this paper we discuss some playing techniques and the sounds that they produce. We apply these playing techniques to the original HANG as well as to two later instrument designs. We also compare the modes of vibration and sound radiation from the three instruments.

2 The three instruments

The HANG is shown in Figure 1. The top (DING) side has 7 to 9 harmonically tuned notes around a central deep note which couples strongly to the cavity (Helmholtz) resonance of the body. The bottom (GU) side has a large hole which acts as the neck of the cavity resonator. The HANG is usually played horizontally in the lap, although it can be played vertically or on a stand.

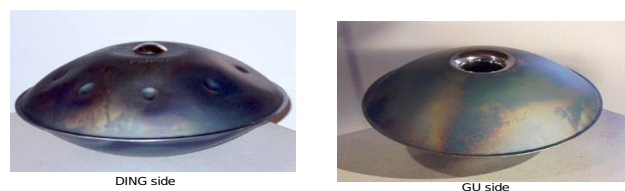


Figure 1. The HANG (DING side and GU side)

The first HANG we tested had nine notes beginning with a centrally located G₃ note area as shown in Figure 1. The notes are tuned to a pentatonic scale. Playing the central G₃ note excites a strong cavity (Helmholtz) in the body of the instrument. The resonator can be tuned by inserting a DUM into the hole, thus changing its diameter or by varying the spacing of the player's knees to change the acoustical "length" of the neck.

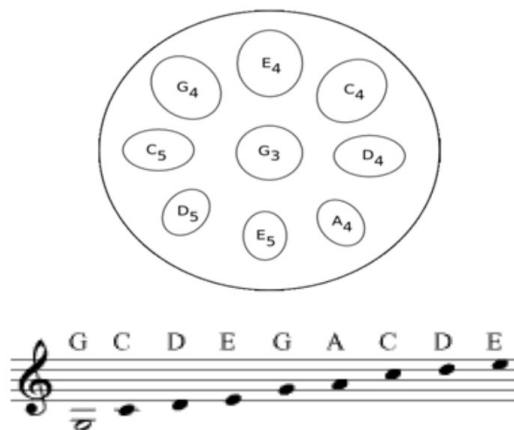


Figure 2. Tuning of the high-voice HANG used in these studies.

The low-voice HANG, the second one tested, had 9 notes beginning with a centrally located F₃ note area. The tuning is shown in Figure 3.

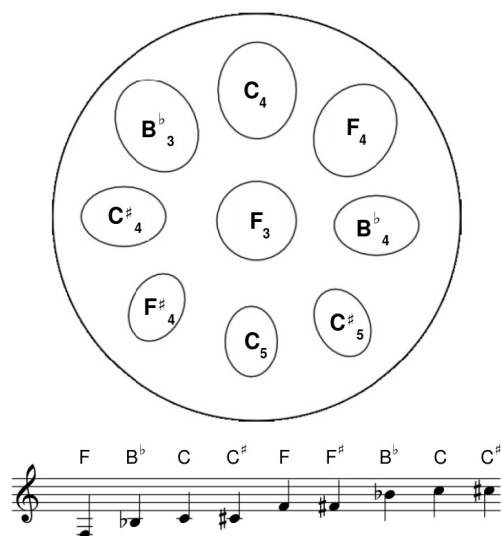


Figure 3. Tuning of the low-voice HANG used in these studies.

To satisfy requests for even deeper sounds, the integral HANG was developed by PANArt in 2006. We have recently tested an integral HANG with seven notes beginning with the central D3 note area. The tuning is shown in Figure 4.

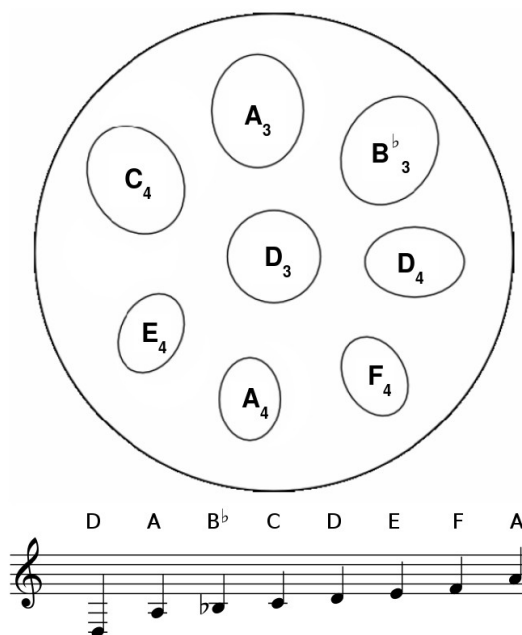


Figure 4. Tuning of the integral HANG used in these studies.

3 Modal analysis

By means of holographic interferometry we have examined mode shapes for individual note areas on all three instruments as well as the entire playing surface at high and low amplitude.

The electronic holographic analyser used for modal analysis of the high-voice and the low-voice HANG has been described previously [3,4]. The object beam is projected on the HANG, and the reflected light is focused on the CCD array of a TV camera, while the reference beam is transmitted to the camera by means of an optical fiber. The resulting interference pattern is read out, pixel by pixel, and the holographic interferogram is constructed by a computer. Thus, an interferogram is created and updated at the TV frame rate (30 Hz in the United States).

Five modes of vibration in the central G3 note area of the high-voice hang are illustrated by the interferogram in Figure 5. In the (0,1) mode of lowest frequency, the entire note area vibrates with the same phase, while in the (1,1)_a and (1,1)_b modes a nodal line bisects the note area. The nodal lines in the two latter modes are orthogonal to each other, so they represent normal modes. These three modes at 178 Hz have frequencies nearly in the ratio of 1:2:3. Also shown in Figure 5 are the (2,1)_a and

$(2,1)_b$ modes having two nodal diameters and frequencies ~ 1.5 Hz which are not harmonically tuned. The three lowest modes in the E4 note area, shown in Figure 6, also have frequencies in the ratios 1:2:3, although the higher modes are quite different from those seen in the G3 mode.

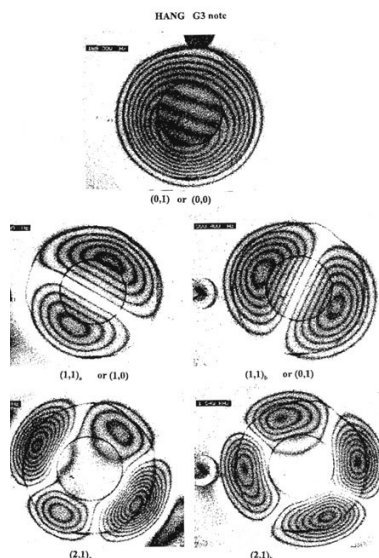


Figure 5. Modes of vibration in the central G3 note area of the high-voice HANG [4].

Holographic interferograms of the low-voice HANG driven at small and large amplitude at frequencies near the first three resonance frequencies of the central F3 note are shown in Figure 6. The mode shapes of the $(0,1)$, $(1,1)_a$ and $(1,1)_b$ tuned in the ratios 1:2:3 are similar to those shown in Figure 5. The coupling between various notes can also be seen. At 348 Hz, for example, the F4 note is strongly driven and the F4# is weakly driven, while at 520 Hz the $(1,1)_a$ mode in the C4 note and the $(0,1)$ mode in the C5 note show appreciable response.

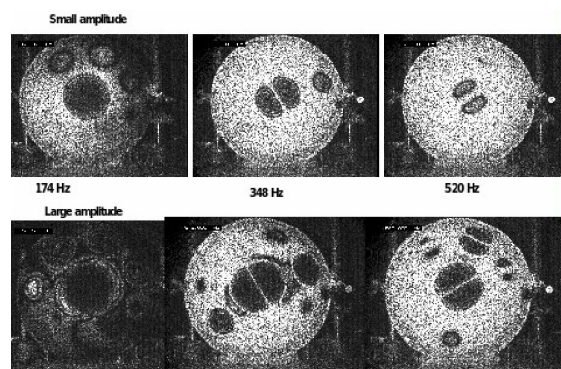


Figure 6. Low-voice HANG driven at small and large amplitude at frequencies near the first three resonances of the central F3 note area [4].

In Figure 7 the low-voice HANG is driven near the first three resonance frequencies of the F4# note. The $(0,1)$, $(1,1)_a$, and $(1,1)_b$ modes are shown, along with coupling to the $(1,1)_a$ mode of the C5# note.

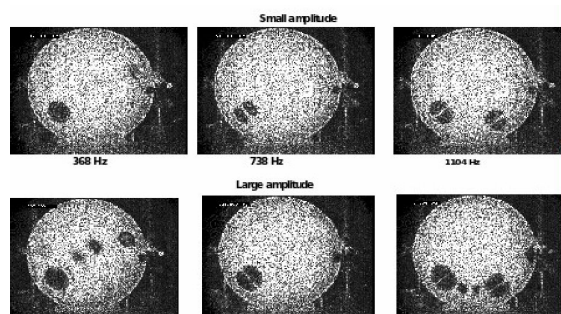


Figure 7. Low-voice HANG driven at small and large amplitude near the first three resonances of the F#4 note [4].

A new holographic interferometer, constructed at Illinois Wesleyan University, has been used to do holographic modal analysis of the integral HANG. An inexpensive speckle-pattern interferometer (or holographic interferometer), constructed at Illinois Wesleyan University, has been used to do holographic modal analysis of the integral HANG. The interferometer is similar in design to the interferometer introduced by Moore [5]. The interferometer makes use of a low-cost diode laser and an inexpensive board level camera (a Unibrain Fire-I board level camera, with a C-mounted zoom lens). The camera interfaces to the computer via the firewire bus, which allows for frame-grabbing without the need for an expensive image-acquisition card.

All processing of the the images captured by the camera is done in software, custom written for the interferometer. Contiguous frames are subtracted to reveal the interference fringes. Pixel values are multiplied by a constant to increase the contrast of the images. In order to increase the signal-to-noise ratio an averaging routine has been implemented. Final images are typically an average of a few hundred frames.

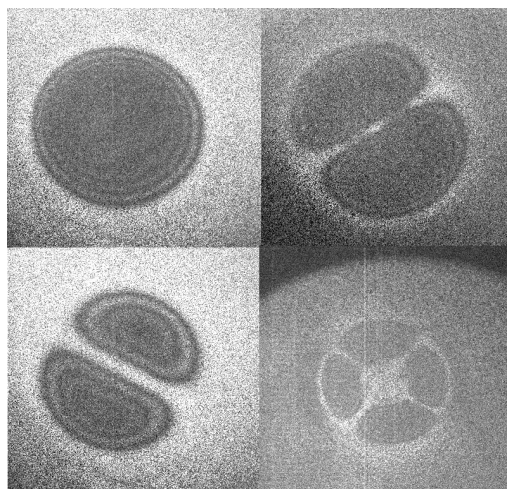


Figure 9. Holographic representations of four resonances of the center note of the Integral HANG: 148 Hz, 295 Hz, 445 Hz and 1344 Hz.

4 Sound spectra

Sound spectra were recorded using a Tektronix FFT analyzer controlled by a laptop computer. Each note area was tapped lightly with a rubber mallet. The spectra for all 8 notes are shown in Figure 9.

Each spectrum shows the three principal harmonics, which have frequencies in the ratios 1:2:3. Also visible in each spectrum is a small peak at 85 Hz, the frequency of the cavity resonance (near F2).

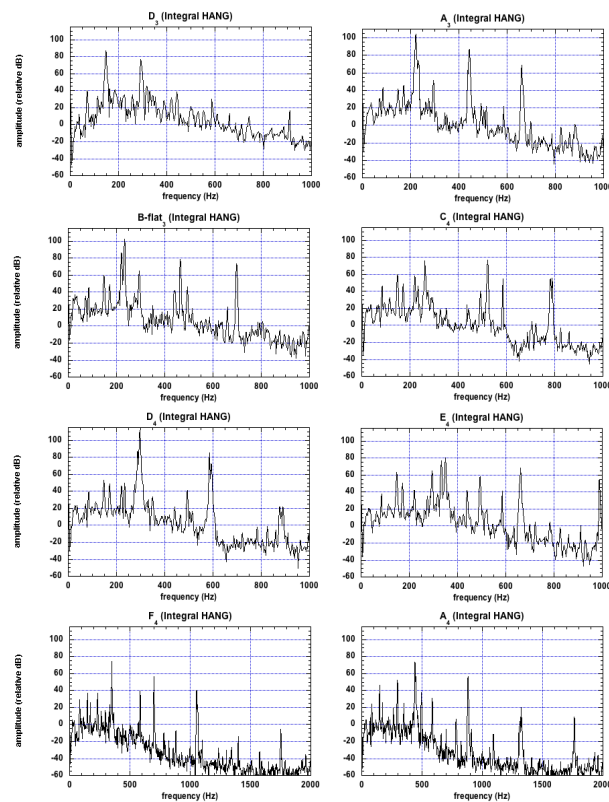


Figure 9 Sound spectra of 8 notes on the integral HANG. Note that the frequency scale is extended to 2000 Hz in the F4 and A4 notes in order to see all three of the principal harmonic partials.

5 Playing techniques

The manner in which the HANG is played has considerable influence on the quality of the sounds that it produces. Playing more or less intensely influences the spectral content, the decay time, and additional features of the amplitude envelope.

In Figure 10 we contrast a soft note say one at *ppp* with a note played loudly at *fff*. The upper panels plot overall amplitude as a function of time and the lower panels plot resonate peaks as a function of time in a manner analogous to a spectrogram. These resonate peaks were extracted by fitting sinusoidal tracks to temporally overlapping short-time Fourier transforms (STFT) of the signal. As expected the overall amplitude is dramatically changed and the loud note rings longer than the soft one. There are considerably more sinusoidal tracks in the intense note. The soft note had but two audibly significant components in an octave relationship whereas the intense notes higher frequency components are inharmonic with respect to the fundamental. In addition, the intense note shows significant amplitude modulations due to beating.

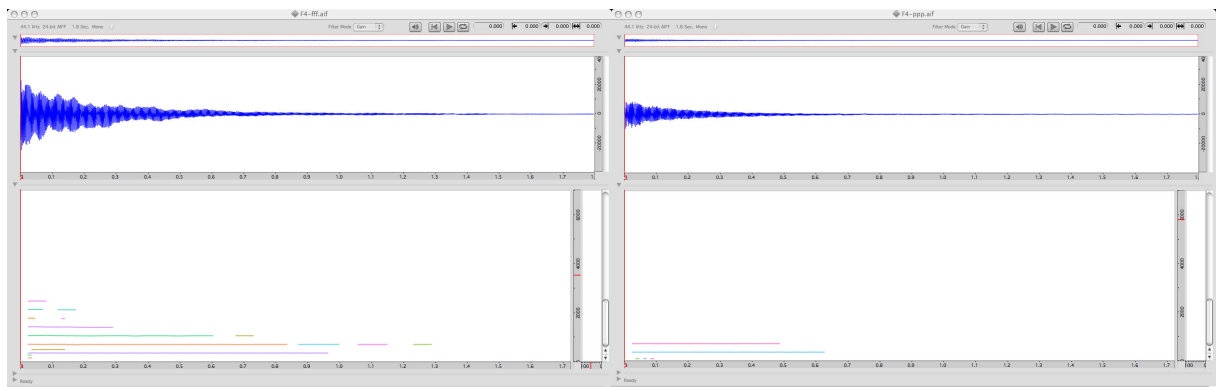


Figure 10 Waveform and spectrogram of a note played at *fff* level (top) compared with the waveform and spectrogram of a note played at *ppp* level (bottom).

An important set of playing techniques involves playing a HANG note with a rapid succession of impacts. This can be accomplished in a variety of ways, the most elementary of which involves playing single stroke roles with the fingers of

alternating hands. As each stroke arrives it finds the HANG in a different state. As a result, each of the notes in the roll has a slightly different timbre. This timbral variation provides a quality to the sound that cannot be achieved by repeating the same sample of a HANG to simulate a roll. To demonstrate this effect we modeled the HANG with filters centered at each of the frequency components. The gains and decay times for these resonate filters were estimated from the analysis. We demonstrate the difference in sound quality by comparing the free running set of resonate filters with a version of the model where the state of the filters remains constant at each impulse.

Another effective way to play a rapid succession of single notes is to use a technique analogous to the way a percussionist using sticks plays a *flam*. This can be accomplished by placing the middle finger just ahead of the index finger when striking the HANG. The arrival times of the two fingers can be controlled by how far they are spaced apart prior to the impact. A variety of timbres can be obtained by controlling the finger spacing in this manner. More complex effects, such as a flurry of notes, can be obtained by arranging the fingers so that the baby finger strikes first followed by the ring, middle, and index fingers in rapid succession.

The HANG's center note with its outwardly extending boss invites a variety of techniques including striking it with a larger surface of hand as with flattened fingers or the base of the palm.

One of the most important aspects of HANG technique is how long the finger or hand remains in contact with the instrument during the stroke. The longer the contact time the greater the damping effect. Many beginning players have difficulty striking the instrument and pulling away quickly making it hard for them to produce notes that ring. One tip is to actually practice making the up stroke rapid separately from the down stroke and then combining them to effectively control the contact time with the instrument

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