Spectral Characteristics of the Musical Iced Tea Can

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Abstract

The musical iced tea can and its acoustic qualities are presented. This instrument, made of resilient metal, fluid, and air, is very heterogeneous, not to mention cheap. Minute changes in the volume of the fluid and the pressure of the air inside, as well the strike position and tilt of the can, greatly affect its acoustics. The two vibrating surfaces (side and top) and their interaction with the fluid and air inside are very complex. Our results show an interesting spectral structure, not unlike that of bells. A goal for this work is to create a computer simulation of the can for musical performance. This paper presents an analysis of the measured impulse responses of seven similar-sized unopened cans, and discusses future work for creating a software model of the instrument.

1 Introduction

Figure 1: *The can.*

The author (Sturm) has long been aware of the musical qualities of the large and inexpensive cans of iced tea (Figure 1) produced by Arizona Beverage Company (ABC).[1] When struck on their side they produce rich tones. Depending on how they are played the cans sound sometimes like bells, gamelan instruments, or voices.

There are several ways to elicit sound from the can. Playing methods include striking the side of the unopened can with a mallet, or striking the top or bottom edges. The sound can be altered by cupping one's hand over the top, dampening the side with the fingers, or tilting the can as it is struck. Unpitched sounds can be created by setting coins on the top, playing an opened can filled with fluid, or slapping the top with the palm. The qualities of the sound change with hit force and position, can tilt, the shape of the cupped hand, and even the proximity of other cans (sympathetic vibration). The can can be made to 'speak' by changing the shape of a hand cupped over its top as it is hit. The composition "First Canstruction" (Sturm 1999) demonstrates the characteristic sounds of the cans, as well as several playing techniques.

This paper introduces the musical iced tea can, presents an analysis of the acoustics of seven unopened cans, and discusses strategies we will use to model it. Accurately parameterizing the acoustics of the can will lead to realistic and flexible models for interactive performance.

2 Procedure

Seven large 700 mL cans of iced tea are purchased and recorded while being struck on the side with a soft mallet. After recording, the cans are weighed, opened and weighed, emptied, dried and weighed, and their physical dimensions measured. The recordings are then analyzed using MATLAB.

The large cans manufactured by ABC have the following physical dimensions: $h_1 = 19.5$ cm, $h_2 = 1.5$ cm, $h_3 = 17.3$ cm, $d_1 = 7.0$ cm, $d_2 = 6.3$ cm (all measurements ± 0.1 cm). This makes the resonating areas of the can: $A_{top} = 31.2 \pm 1.9$ cm^2 and $A_{cyl} = 380.4 \pm 22.8$ cm^2.

The densities of the different fluids were measured to be $1.10 \pm .01$ gm/mL. The volume of the fluid inside the can is calculated from the fluid mass and density.[2] The results of these measurements are shown on the left side of Table 1. R_V is the ratio of the volume of the fluid to the volume of the can (found to be 700 ± 7 mL).

The recording of the cans were done using two AKG C 414 B-ULS microphones. This is a large diaphragm condenser microphone with several user-settable polar patterns. The sensitivity of the microphone is 12.5 mV/Pa, and has a signal to noise ratio of 80 dB (AKG Acoustics 2004). The microphones were positioned approximately 4 inches away from the side and top of the can (Figure 2). For each microphone the hyper-cardioid pattern was used and the bass attenuation disabled.

[1] `http://www.arizonabev.com/`

[2] This assumes the pressure in the can is not great enough to compress the liquid contents.

Figure 2: The recording setup.

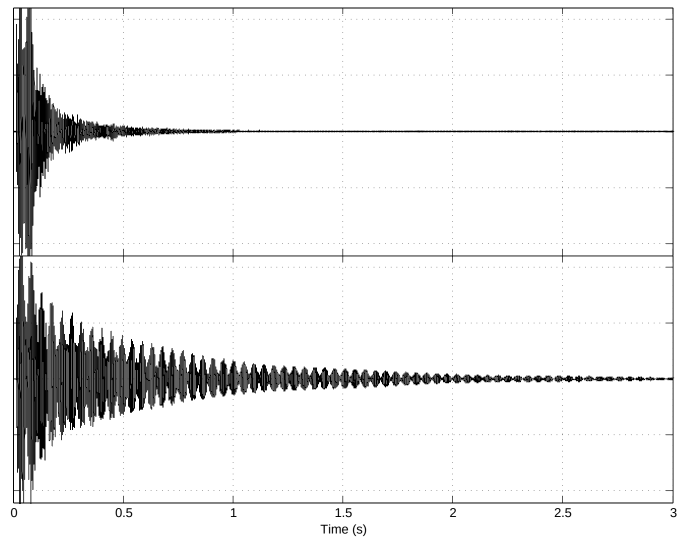

Figure 3: Time-domain waveform recorded from top (top), and side (bottom), of can #5.

For the first set of recordings the can is held still with a finger on the top rim and hit once on the side approximately in the center with a felt-covered xylophone mallet. For the second set of recordings the can is allowed to recoil from the impulse. Approximately the same force was used for each strike. The microphones were set at approximately the same gain and recorded digitally onto two tracks at 44.1 kHz sample rate, 16-bit resolution.

3 Results

The time-domain waveforms of can #5 are shown in Figure 3. An exponential decay time is apparent. The audible ring time of a can (when not shaken before striking) is usually no longer than 2 seconds. Not surprisingly, most of the acoustic energy is emitted from the side of the can, at least when it is struck on its side. On the right side of Table 1 are the ratios of energy emitted from the side to the top of the can, over the durations 0 – 0.2 seconds, and 0.2 – 2.0 seconds.[3] In most cases more energy was emitted from the top of the can during the impulse. But after the impulse most of the energy is radiated from the side.

An interesting feature in Figure 3 is the beating pattern at about 21 Hz. This beating is apparent immediately after the impulse. A spectral analysis of can #5, shown in Table 2, shows that this is the result of the first two partials separated by 21.5 Hz.

To analyze the frequency content of the struck cans, Fourier transforms were performed on entire recordings (~ 4 seconds, including attack). Figure 4 shows the normalized spectrum of the side of can #1. Frequencies below 150 Hz were from extraneous sources. All of the energy in frequencies above 1500 Hz comes from the attack and sometimes the buzzing of the can-opening tab on top of the can.

For can #1 the first partial is the loudest. For the rest of the cans however, the loudest partial is actually the second component, not the first. This is shown in the first two columns of Table 2, which also shows the relationships among eight significant spectral peaks for each can. What is seen is that there are three low inharmonic partials, and the rest are close to integer multiples of these. This is clearly a result of three interleaved harmonic spectra.

Sonograms of a recording for can #6 are shown in Figure 5. In this case the can was allowed to recoil from the strike, which created an audible wobble in the sound. The exponential decay of the partials is quite visible in this figure. An interesting feature is seen in the frequency region between 1 – 2 kHz after 0.1 seconds. This is the effect of the moving fluid on the vibrating cylinder and top. In addition, when the frequencies start to descend at 0.1 seconds in the top of the can, there are partials at approximately 1600 and 3000 Hz measured from the side of the can that increase in frequency.

4 Discussion

Initially one microphone was used to capture the acoustic radiation near the side of the can. After audition however, it was found that the recordings were quite ‘uncanny,’ especially during the attack. By capturing the acoustic radiation

[3]The impulse time is at 0 seconds.

CAN	m_{total} (g)	m_{open} (g)	m_{can} (g)	V_{fluid} (mL)	R_V	$\frac{RMS_{side}}{RMS_{top}}$ 0 – 0.2 s	0.2 – 2.0 s
1	739.8	739.7	29.3	645.8	.923	0.47	1.02
2	747.3	747.2	29.6	652.4	.932	0.61	2.99
3	750.0	749.6	29.4	654.7	.935	0.56	2.58
4	750.5	750.5	29.8	655.2	.936	1.23	3.60
5	743.7	743.4	29.7	648.8	.927	1.69	6.64
6	755.3	755.3	29.6	659.7	.942	0.94	4.25
7	743.3	743.1	29.3	648.9	.927	0.89	4.55
	$\pm.5\%$	$\pm.5\%$	$\pm.5\%$	$\pm.6\%$	$\pm.6\%$		

Table 1: Physical measurements and RMS analyses of the seven cans. More energy is emitted from the top of the can during the attack (0 – 0.2 seconds), than the side.

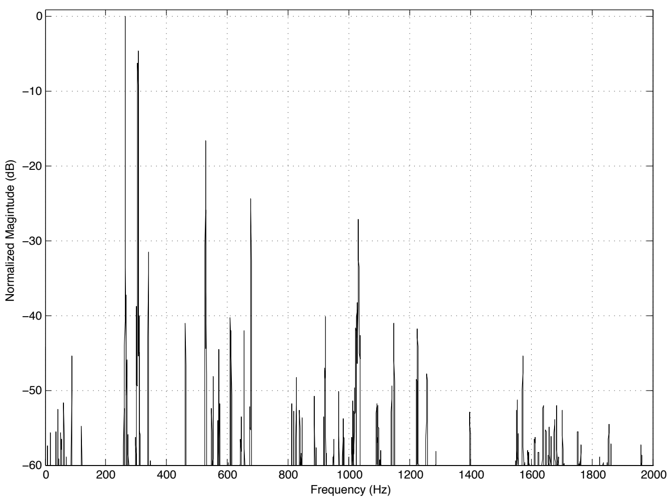

Figure 4: Normalized spectrum for side of can #1 (including attack).

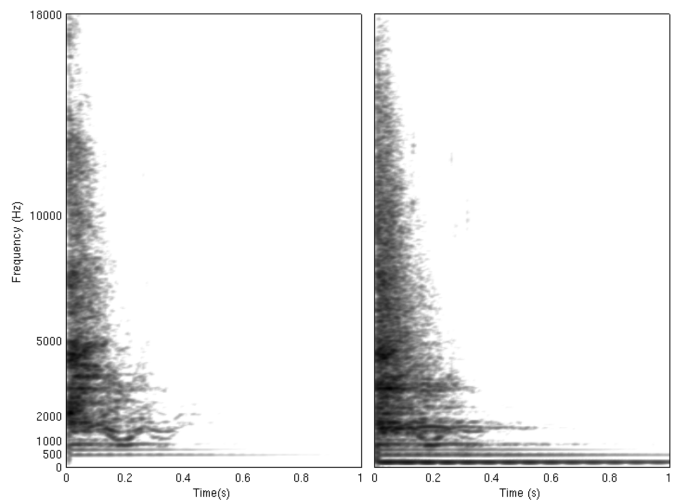

Figure 5: Sonograms of can #6 for top (left) and side (right).

from the top of the can a much more realistic recording is obtained. The importance of the top of the can to the sound of the attack is further verified by the ratio of energies in Table 1.

Obviously the sustained sound of the can comes from the side. The lowest frequency partials are not at all present in the top, as seen at the bottom of Figure 5. These low components last much longer than anything higher, all of which quickly dissipate after about 0.4 seconds. This signals a major mode of vibration along the circumference of the cylinder.

Although initially sounding inharmonic, the musical iced tea cans clearly demonstrate harmonic relationships in its partials. The feature of the beating partials, interleaved harmonic structures, and the louder second partial are similar to the acoustics of bells (Fletcher and Rossing 1991) and Tibetan singing bowls (Essl and Cook 2002).

Not all cans sound the same. The amount of tonal variation among cans of the same size is interesting. The seven cans chosen had perceivable differences in pitches. Before recording, the seven cans were numbered in order of ascending pitch. This is confirmed by the values in f_1 in Table 2, but f_2 shows a few interesting deviations. No statistically significant relationship has been found between the perceived pitches and the physical dimensions of the can, e.g. R_V in Table 1. More accurate measurements of the fluid volume and air pressure might make the relationships apparent.

It is interesting that the moving fluid affected the top of the can more than the side. Perhaps this is caused by the small column of air between the fluid and the top. This can be explained, along with the three interleaved harmonic spectra, by research into the vibrational modes and fluid–shell interaction of the can.

4.1 A model of the can

This curious and equally refreshing instrument presents several challenges for a computer simulation. When the can

CAN	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8
	(Hz/dB (relative))							
1	264.1/0	306.1/-5	339.7/-32	$2.0f_1$/-17	$2.0f_2$/-40	$3.02f_2$/-40	$3.03f_3$/-27	$4.01f_2$/-42
2	270.1/-16	305.8/0	350.7/-39	$1.99f_1$/-23	$2.0f_2$/-42	$2.0f_3$/-34	$3.12f_2$/-41	$3.00f_3$/-45
3	276.5/-10	309.5/0	360.4/-34	$1.99f_1$/-24	$2.0f_2$/-42	$2.0f_3$/-34	$3.18f_2$/-46	$2.99f_3$/-54
4	286.6/-3	312.0/0	381.1/-45	$2.0f_1$/-20	$2.0f_2$/-38	$1.76f_3$/-44	$2.94f_3$/-48	$3.90f_1$/-49
5	290.4/-3	311.9/0	388.2/-25	$2.0f_1$/-22	$2.26f_2$/-39	$2.0f_3$/-39	$3.19f_2$/-40	$4.13f_3$/-49
6	298.6/-8	312.2/0	403.2/-26	$2.0f_1$/-20	$2.0f_2$/-41	$2.0f_3$/-35	$3.20f_3$/-39	$4.10f_3$/-49
7	303.6/-5	315.7/0	411.2/-28	$2.0f_1$/-22	$2.0f_2$/-42	$2.0f_3$/-32	$3.21f_2$/-46	$4.10f_3$/-52

Table 2: Spectral relationships for seven cans. Three interleaved harmonic spectra are clear.

remains stationary it can possibly be modeled using modal synthesis (Adrien 1991). A similar approach is taken by Karjalainen, Välimäki, and Esquef (2002) in the modeling of bells. When the can is tilted however, the modes and spectrum are greatly affected by the fluid. Furthermore, when the can is allowed to recoil from the impact the modes of the can are dynamically affected by the moving fluid. Modeling the interaction between the resonating cylinder and the moving fluid will be complex.

The interleaved harmonic spectra will probably be modulated by can tilt and fluid motion. Further work in determining these effects will lead to a physically informed spectral model of the can (Cook 1997). Though what happens to the acoustics when a can the size of a car is simulated will require a deeper look into the physics, and perhaps modeling with digital waveguide meshes (Smith 1997).

It is hoped that with more thorough spectral analyses of the cans under these conditions that a better parameterization is possible, and a computer simulation of the can will be possible. What has been determined so far is the importance of the side and the top of the can for creating 'canny' sounds. Using modal synthesis then the top and side can be represented as two lattice filters excited by an impulse. A more accurate model will permit the filters to be modulated by the state of the fluid and air inside the can. This model is diagrammed in Figure 6.

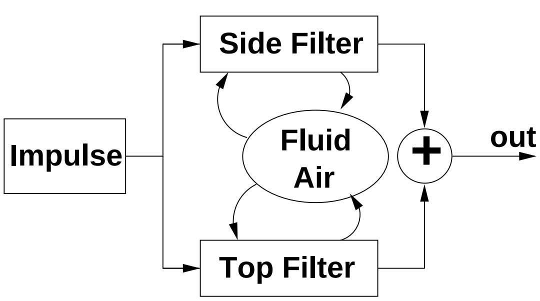

Figure 6: A two-filter model of the can. Each filter is modulated by the state of the internal fluid and air.

5 Conclusion

The musical iced tea can has been presented as an acoustically interesting and refreshing instrument. An analysis of its acoustics reveals similarities to bells. The top of the can is important in shaping the attack portion of the strike, while the side of the cylinder resonates with three interleaved harmonic spectra. The can presents several challenges for modeling with its inhomogeneous composition. The complex interaction between the fluid and the vibrating membranes create interesting effects. A modal model might be possible if the can is stationary; but with fluid movement, a more physically informed model will be necessary. With a suitably parameterized model for the can, a virtual ensemble of cans–a 'Canelan'–will be possible.

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