THE HARMONICA MATERIALS MYTH

The case against a perceptible effect of comb material on instrument tone.

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March 2018

SUMMARY

The acoustic activity of the harmonica comb is so minuscule that its effect on the sound is completely masked by the sound of the modulated air stream that comes directly to the ear from the reed. Among dozens of blinded participants at SPAH conventions, none have been able to distinguish one comb material from another by listening or playing.

Lacking supporting theory or evidence, audible effects of comb materials remain an imaginary product of wishful thinking.

What can be asserted without evidence can also be dismissed without evidence…..Christopher Hitchens

DOES IT MATTER?

It matters if –

- you wish to understand the acoustics of the harmonica.
- you wish to avoid paying extra for a unique sound that the harmonica cannot deliver.
- you sacrifice real advantages of one material for the supposed superior tone of another.
- you wish to avoid distractions in your pursuit of harmonica artistry.

If none of these factors are important to you, then you need not read further.

HISTORY

About 1993, I sought to produce exotic sounds by making harmonicas of exotic materials. With a degree in mechanical engineering, intermediate chromatic harmonica chops, a small metal-working shop in my garage, and lots of enthusiasm, I made combs and reeds of various materials.

Sadly, the results were consistently disappointing. The tones were not perceptibly different among a wide variety of materials. Either there were no differences or my weak, old ears were unable to hear them. Instead of building things that didn't seem to work, I decided to find out which was true and why.

To understand the acoustics of the harmonica, I obtained the books listed in the bibliography. I also accessed information on Wikipedia and other on-line sources. None of this reference material yielded any theoretical support for the notion that the tone of a harmonica would be affected by the properties of the materials of which it is made. All of the indications are quite the opposite. The books state that the materials of wind instruments do not affect the sound.

About 1995, there were statements on the Harp-L forum about comb materials. They claimed that "wood sounds warm," "metal sounds bright" and "plastic sounds plasticky." Hohner advertisements claimed that different types of wood produced different tones. Armed with recent personal experience and some "book learning," I brashly challenged these statements. This led to a years-long discussion that came to be known as "the Materials Debate." The HARP-L archives contain many posts on the subject, especially by me and Douglas Tate. The discussion also started on the Slidemeister forum.

Although the technical literature had some information on the effect of materials on musical instruments in general, there was nothing specifically about harmonicas. The possibility remained that younger, more sensitive ears could hear differences that mine could not. To find out, it was necessary to test the perceptions of others. The most likely candidates could be found at harmonica conventions. This led to three public tests:

SPAH, August 1997, organized by Douglas Tate and I
Buckeye, April 1999, organized by John Thaden and I
SPAH, August 2010, organized by Brendan Power and I

My main role in all of these tests was the preparation of the harmonicas and other test equipment. The tests are described later in this document.

Finding no support in acoustical theory and no one able to distinguish among different materials by listening to or playing the instruments, I concluded that comb materials have no perceptible effect on harmonica sound. I pronounced the materials effect a myth. Several believers arose to defend it.

The "Hans Christian Andersen" argument arose that there could be a "true princess" who, instead of feeling the pea under the mattresses, could detect subtle differences in sound that are imperceptible to us "commoners." As a wearer of hearing aids, I can't deny that some people can hear better than others.

To find such a "princess", I offered to wager $1000 that no person could demonstrate the ability to perceive material differences under controlled conditions. For about 20 years, there have been no takers. A few have claimed to be able to win but had pecksniffian objections to "gambling." Gambling is defined as a "game of chance played for money" For a person truly able to hear material differences, the outcome is known, it is not a game of chance and not gambling. If I lose, it would be worth $1000 to learn that I am wrong and end the argument. If even a single person could reliably detect different comb materials by the sounds of the harmonica, then a materials effect would be confirmed.

Where there is a preference or expectation, the subjective perception of very subtle effects often leads the listener astray. That is why blinding is required for drug tests and wine tastings.

<u>ANALOGIES</u>

I believe that the Materials Myth arises from a false analogy with stringed instruments. The energy of string vibration passes through the bridge and soundboard of a violin or guitar. The vibration of the soundboard pushes against air molecules and generates sound waves that travel through the air to the ears of the listener. The quality of sound

depends on the spacing along the spectrum of resonances of parts of the top, back, and cavities. For extensive information about stringed instrument acoustics, look on the internet for the writings of Carleen M. Hutchins.

The harmonica is entirely different. The vibration of the reed alternately allows and prevents air flow through the slot. The operation of a reed was likened to a siren by Helmholtz in the 19th century. These flow/pressure variations create sound waves that travel directly to the ears of the listener. The amount of sound absorbed, reflected, or transmitted by the comb and covers is minuscule in comparison and is masked by the siren sound described above. More about masking later.

There is a much better analogy for the harmonica. It is a person whistling. Exchange the reed for the whistler's pucker, and all of the same acoustical effects are in action. The small volume of the reed chamber becomes a part of the player's much larger embouchure and brings the vocal resonances into play. This is why a good player sounds good on almost any harmonica but poor playing isn't improved by a good harmonica.

With a bit of practice, you can place a bare reed plate on your lips and blow or draw a full, rich harmonica tone. The fact that the comb and covers are absent demonstrates that they play no important role in sound production. Their function of the comb is to direct your breath to the reeds and the function of the covers is to keep your hands off of the reeds.

ACOUSTICS

Pitch and Wavelength

Sound waves travel through room-temperature air at approximately 1125 feet per second. This accounts for the delay between the flash of lightning (traveling at 186,000 miles per second) and the thunder that follows. The distance that a sound wave travels during one cycle of reed vibration is the wavelength. The lowest pitch/frequency that can be found on a 16-hole harmonica is C3 which has a frequency of about 131 herz (cycles-per-second) and a wavelength of about 103 inches. The highest pitch found on a harmonica is C7 with a frequency of about 2093 herz and a wavelength of about 6.5 inches.

Low pitched musical instruments such as the bassoon, tuba, and string-bass tend to be long and large. In contrast, the high-pitched piccolo is very short and small.

Resonance.

The shortest tube (open at one end and closed at the other) that can contain a resonant standing wave is one-quarter wavelength long. At C7, the highest harmonica pitch, a quarter-wavelength is about 1.6 inches long…more than twice as long as any air passage within the harmonica. If one considers the lower pitches of the harmonica, then the lengths of the air passages are smaller fractions of the wavelengths. For this reason, no chamber of a harmonica can resonate as does the air column in the tube of a wind instrument. Attempts have been made to add resonant chambers to a harmonica. The result is large, awkward, and resembles a pan-flute.

The construction of the harmonica does not allow for the presence of resonant standing waves of any frequency within the materials. The discontinuities of density and elasticity at the boundaries of the comb, reedplates and covers suppress resonance. The openings in the reedplates and comb have the same effect. A single crack makes the Liberty Bell useless for its intended purpose. If an engineer were to design an object to resist resonating, (except of course for the reeds), he could hardly do better than the harmonica. Resonances within the harmonica structure would have the undesirable effect of making some notes louder than others.

In a Helmholtz Resonator, found in a jug or ocarina, the air contracts and expands with each cycle. The resonant frequency is determined by the sizes of the chamber and the openings. The reed chambers are not large enough to resonate at frequencies within the range of the instrument. However, combining the volume of the reed chamber with the volume of the player's embouchure makes an enclosure large enough to resonate at the frequency of the note played. The player can change the size of his embouchure to match its resonance to the note being played as in singing. This is why a good player can sound good on almost any harmonica but a poor player doesn't sound good on even the best harmonica. This is very much like singing or whistling.

Reeds are the only resonant parts of a harmonica.

Masking.

"Masking" occurs when a sound is inaudible in the presence of a louder sound. The masking effect is particularly powerful when both sounds have the same pitch as in the case of the harmonica. See "masking" on Wikipedia. This is like starlight in the daytime. We know that it is there because we see it at night but it is masked by the much brighter sunlight. A pin dropping can be heard all over the Mormon Tabernacle…but not while the organ is playing.

For the 1997 test at SPAH, I attached an extra reed to a reedplate. It protruded out the back so that I could pluck it while the instrument was being played. I stood with my back to the audience and plucked the reed without playing the harmonica. The audience heard it faintly but distinctly. While I blew the same note, the plucking could not be heard. Although the sounds from the reed as a bell and from the comb, reedplates and covers emanate when the reed vibrates, they are masked by the much louder blown note.

In order for the tone to be affected by differences of comb material, its frequency spectrum would have to be altered in different ways by the comb…an even more subtle difference. But because sounds from the comb are masked, this source of comb effect cannot operate.

TESTING

Although acoustical theory does not support a materials effect, there remained the "bumblebee" argument. " According to an old (now-controverted) aerodynamic calculation that doesn't consider wing-flapping, the bumblebee should not be able to fly. (Actually it explains why the bumblebee cannot glide.) However, the bumblebee doesn't know this and flies anyway."

SPAH97

Douglas Tate and I decided to try to find listeners who could distinguish one comb material from another by the sounds alone. We organized a materials seminar at SPAH97 that included a blind comparison of harps of various materials.

With the help of Harp-L members, we obtained combs for about 10 Hohner Big River harps of the following materials: Doussie Wood, ABS black plastic, Balsa Wood, Titanium, Clear Acrylic, Lead, Aluminum, open-cell Foam Plastic, closed-cell Foam Plastic, and Concrete. We reasoned that if materials perceptibly affected harmonica tone, these would maximize the differences.

The harmonicas were selected at random from groups of four and played by John Walden behind a thin scarf suspended from a broad-brimmed hat. They were not amplified . Twenty-eight SPAH97 attendees volunteered to record their selections on forms provided. As a preliminary to each part of the test, the four harps were played and their comb materials were announced. Two of the 4-harp groups were played by Walden and one group was played on a machine.

None of the participants were able to significantly exceed the 25% accuracy expected for random guessing. An interesting result of the tests were instances where the same material was played two or more times in succession and the participants identified different materials. They heard differences that could not be attributed to comb materials.

After the results were announced, the conditions of the test were criticized.

- There was noise in the hallway.
- Groups of four combs were confusing.
- Reedplate differences obscured comb material differences.

This test could not prove that a perceptible materials effect did not exist. It demonstrated that none of the 28 participants were able to perceive it under the controlled conditions of that particular test. However, it greatly lessened the likelihood of a perceptible materials effect.

Buckeye 99

John Thaden conducted a test at the Buckeye Harmonica Convention in 1999 that was designed to avoid the criticisms that arose from the SPAH97 test.

- Care was taken to use a quiet, closed room.
- A smaller number of comb materials were compared.
- A single set of reedplates were used.

The covers and reedplates were attached to the jaws of Vice-grip pliers. The combs could be very quickly clamped in place and removed. This was not as bad as it sounds because the clamping force was exerted only at the locations of the cover screws.

After the results were announced, the test conditions were criticized.

- The clamping device was too artificial.
- The few seconds required to replace the comb was too long.

The test could not disprove the existence of a materials effect. As in the SPAH97 test, none of the participants could perceive it under the conditions of that particular test. It made the existence of a materials effect even less likely.

SPAH2010

Acoustical arguments and two blind tests had convinced many that materials differences were not perceptible to listeners. However, some clung to the notion that such differences are perceptible to players.

Harmonica virtuoso Brendan Power proposed a blind playing test with three significant differences:

1. The participants would not be asked to identify materials but to rate properties of their sounds on a scale of 1 to 5. He was interested in the player's perceptions of "bright", "thick", "loud", "balanced", and "pleasing." He did not further define these properties. Thus there were no right or wrong answers.

2. Brendan recruited six professional, virtuoso players (whose names you would probably recognize) to participate.

3. The participants would play a harmonica assembled on combs of seven different materials…bamboo, brass, pear wood, Corian plastic, Dymond laminated wood, aluminum, and clear red plastic.

An external weight was attached at the cover screws to mask comb-weight differences. The fronts of the combs were all painted the same color. The participants were blindfolded at the start but the blindfolds were discarded part way through the test. They were encouraged to simply play but not visually examine the test instrument.

The harmonica was assembled using combs of various materials. Then it was passed around for the six test subjects to play and rate the sound attributes. It was swabbed with alcohol after each use. It was passed around ten times.

Six players rated five attributes ten times for a total of 300 ratings. 0.03% of the ratings were 1. 10% of the ratings were 2. 64 % of the ratings were 3. 25% of the ratings were 4. 1% of the ratings were 5. Because 89% of the ratings were 3 or 4, the players seemed to agree that whatever differences they perceived were small.

As a control, the brass comb was presented to the players four times in succession without being disassembled. The ratings for the brass combs were as varied as the ratings for the other mixed set of comb materials. Within this set, the perceived differences could not be attributed to differences of comb material.

Two of the six players gave the same set of attribute ratings to all ten of the combs presented. They were unable to detect any differences among the various comb materials.

After the results were announced, the test conditions were criticized saying that the harmonica had leaks between the combs and reedplates. Although the harmonica may not have been perfectly leak-tight, I found the reedplates and combs to be reasonably flat and made sure that the screws holding them together were snug.

This blind test offered the players the opportunity to demonstrate the ability to discern comb material differences. None was able to do so in this particular set of circumstances.

Hohner ACE48 Chromatic Harmonica

In the past, Hohner has claimed that different types of wooden comb materials have different sounds. Currently, they claim that inserts (called "Acoustic Coupling Elements") of different materials plugged into openings in the comb can "enable uniquely variable sound design." "Removable Acoustic Coupling Elements (ACE) modify acoustic impedance to create your own tonal color…" For all of the reasons given above, this claim is laughable.

The additional discontinuities within the comb at the boundaries of the "elements" make it even less likely that the comb could be acoustically active.

If Hohner understands the acoustics of the harmonica, then their claims constitute false advertising. If Hohner does not understand the acoustics of the harmonica, then the claims demonstrate incompetence.

I suppose that they base their claims on easily-obtained testimonials. Then they offer whatever will sell to the believers. They are understandably uninterested in debunking the materials myth.

However, the ACE48 is an ideal vehicle for a blind test. Switching comb materials for the same set of reedplates is quick and convenient. It would only be necessary to recruit participants and set up controlled test conditions.

These include:
- Test open to the public. A SPAH convention seems ideal.
- Participants most likely to be able to discriminate among differences in sound.
- A procedure that denies participants knowledge of the materials being played except for their sound.
- A statistically significant number of random playings of the various materials.

CONCLUSION

Acoustical theory not only fails to predict a perceptible effect of comb material on harmonica tone, it predicts quite the opposite.

If even a single person could be found who could reliably associate comb materials with characteristic harmonica sounds, then the existence of a materials effect would be confirmed. Extensive efforts to find one among SPAH members have been thus far unsuccessful. Before a test, believers are confident that they can hear tonal differences attributable to comb materials. All have thus far failed to demonstrate this ability during the controlled conditions of the test. Afterwards, many blame their failure on imperfections of the test conditions.

Born of wishful thinking, defined by a false analogy, and sustained by anecdotes, testimonials, and advertising claims, a perceptible materials effect remains a myth.

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WIKIPEDIA, (masking, pareidolia, apophenia, confirmation bias)