Lessons from building a wooden tongue drum

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The drum waiting for the finishing oil to polymerize

This article is not a step by step construction guide for building a tongue drum – those can be easily found on YouTube and elsewhere. Instead, here is a compilation of lessons I learned, often the hard way, when I built mine: methods, difficulties, and caveats that can help you learn from my mistakes instead of making your own. I focus in particular on the question of chasing the desired acoustics, which is often underexplored.

Contents

The challenge

A wooden tongue drum (not to be confused with the metal variant), a.k.a. a log drum, is essentially a thick-sided wooden resonator box with tongues cut into its top that make sounds when struck. If built well, it can make hauntingly beautiful music. If built not so well, it can make a lot of noise. Both work fine as a toy for small children, but I built mine as a gift for my grandson who is a talented pianist, so I had to do well, and this is where things got complicated. Unlike other wood shop projects, where if you work with precision then success is a given, a drum involves physics and musicology as well as joinery, and its success seems to involve some luck and magic as well... My neighbor, who observed me grapple with the acoustic problems for weeks, informed me that this was “the most masochistic project” she’s ever seen! :-)

Wood selection

The accepted wisdom is to use padauk for the soundboard, and any of a number of hardwoods for the box. My research found that in practice people are using a wide range of species: they advocate padauk, wenge, cherry, walnut, mahogany and on occasion even pine. And the sounds generated (at any rate, in home-built drums) bear little correlation to the choice made: in some of the videos that compare a number of drums built by the same person, an all-pine drum might sound better than one made of hardwood. My choice of sapele and cherry was dictated by the lumber available to me (which definitely lacked padauk).

Box design

As I often do with a new project, I spent some weeks scouring the Internet and learning from the many good folks who generously share their builds. I also bought and perused a couple of construction article PDFs. I then integrated everything I learned, and this design came out.

The drum is 30x19x15 cm in size, and is made of 20 mm cherry for the box, 16 mm sapele for the soundboard on top, and 18 mm birch plywood for the bottom, with has a 35 mm sound hole at its center. There is a wide support block under the soundboard, immobilizing it up to the base of the tongues. This also supports the bottom board, along with three ledgers.

Top, bottom and inside views of the finished drum

I built the whole box with hand tools from raw planks, dimensioning everything with hand planes and a shooting board. This gave me panels that are flat and true, allowing the use of butt joints throughout without loss of strength. Some builders use dovetails, splined miter joints and other methods, which is fine but not really necessary. I won’t go here into more details; if you’re reading this I imagine you have the required joinery skills.

Soundboard design

The big mystery is how to design the layout for the tongues. There are only a few basic patterns being used repeatedly in the videos and blogs online, but nobody speaks of how their shapes were derived, and what the pros and cons of each layout are... it looks like most builders are just copying patterns from other builders. Having no other recourse, I did the same thing – picked a pattern that looked pleasing, assumed it worked on the source drum, then stretched and morphed it in Photoshop to fit my soundboard (easy) while meeting my acoustic goals (not so easy, as it turned out).

To estimate the length required to attain a given pitch I applied the formula for a vibrating cantilever beam:

$f_1 \approx 0.1615 \times h/L^2 \times \sqrt{(E/\rho)}$, where

- f_1 = frequency in Hz
- h = thickness in meters
- L = vibrating length in meters
- E = Young's modulus in Pascals
- ρ = density in kg/m^3

This formula assumes a rectangular beam, without a mushrooming end, but it does give a first approximation. The constants E and ρ are available at the Wood Database; ever the physicist, I went the extra mile to calculate E/ρ from frequency measurements on an actual piece of the very sapele I had on hand. All this gave me calculated lengths for the frequencies I wanted.

Of course, the formula is for an idealized beam, not for a complex, non-uniform organic material like wood. The calculation put me in the right ballpark, but would still require substantial tuning, because the wood had its own ideas. No disaster: my original plan was to make an A minor pentatonic drum, but when the actual pitches were too far off, I simply examined multiple other options and selected a scale whose notes were close to the tones the sapele had deigned to give me. This turned out to be G3–B3–D4–F♯4–A4–B4, a subset of the G major scale, including the notes of the G major 9 chord. (If you think I was fluent in all this music stuff, you're wrong... but I found the internet wide and instructive, as always.)

Tuning the tongues

In theory, tuning is simple: you measure the pitch a tongue produces with a *tuner*, and either remove wood from under the tip of the tongue to raise the pitch or remove it from under the root of the tongue to lower it. You can use a small forstner drill bit or a chisel, and reiterate until the tuner tells you you're good, then move to the next tongue.

In theory, that's all there is to it.

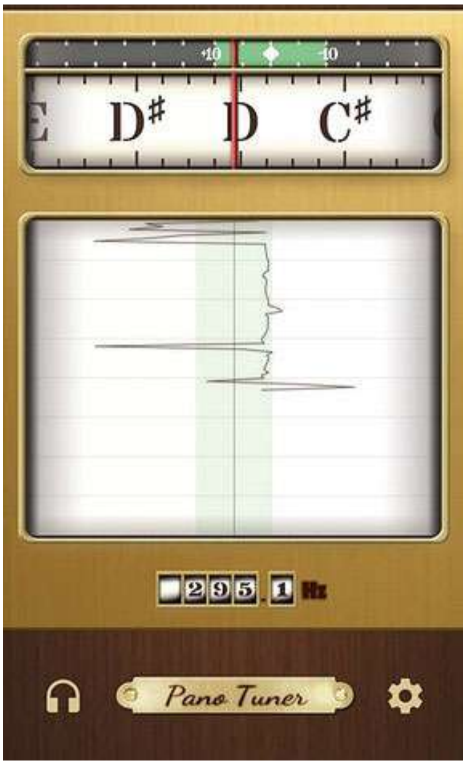
In reality, there are numerous complications, such as:

- Changing the pitch of a tongue may cause it to lose its melodiousness and become clunky, or thunky, or muddy (technically, change its waveform envelope for the worse).
- Changing the pitch of one tongue may move the pitch of another tongue.

- A tongue being tuned may suddenly decide to develop a buzz, or a higher volume than adjacent tongues, or any other inexplicable and annoying phenomenon.

If you're curious to know what is going on, you need good insight into the behavior of your tongues during the second or two following a mallet strike. For this, you need two tools:

1. A **tuner**, to measure the pitch being emitted. This used to be a physical instrument, but now they are apps on your phone. You need one that gives you the frequency heard (measured in Hertz), the closest note (as in A4, or F#3), and the deviation from that note in cents (hundredths of a semitone). I found I needed a few of these apps, because not every app could "latch" onto the brief sound a given tongue makes, especially in the beginning of the tuning journey. Fortunately, many of them are free. For example, here are two that I used:

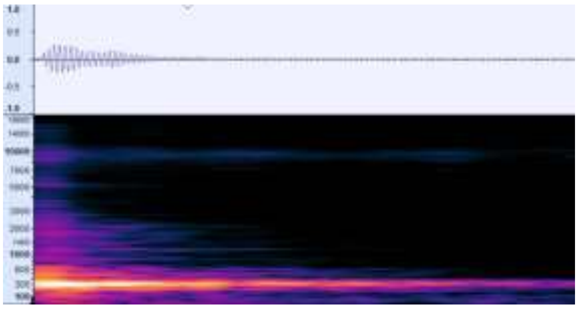


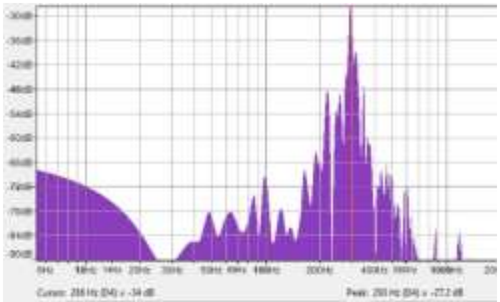
2. A **spectrum analyzer**, to get more precise data about all the frequencies present in a sound (the tuner only shows a single frequency). This is more of an "offline" tool (the tuner works in real time). To use it I had to record the sounds with my phone and feed the MP4 files to Audacity for Windows, a powerful application that gave me the waveform, spectrum and spectrogram for each tongue (see screenshots below).

Using a tuner alone will tell you that a given tongue vibrates at 438 Hz, which is close enough to an A4 note (440 Hz). Adding a spectrum analyzer would allow you to say things like "This tongue sounds to the tuner like 438 Hz, but the spectrum shows that it has a dominant frequency of 437 Hz and a second frequency of 442 Hz only 5 decibels weaker; but after 100 milliseconds the 442 Hz dies out, and after 400 ms the 437 Hz veers to 439 Hz and dies out by 500 ms. There are also a number of spurious frequencies above 460 Hz, but they're weaker than –25 db". In this (fictitious) example the tongue's sound would be somewhat compromised because of the spurious frequencies. Now, without the spectrum analysis all you'd know is that it doesn't quite sound clean, but not why; and the why could lead you to useful conclusions, such as noticing that a spurious frequency belongs to an adjacent tongue that is coupled to this one through a bad glue spot at their root line.

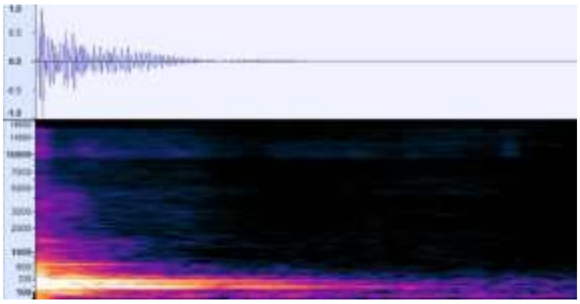
The following two examples, made in Audacity, illustrate the idea.

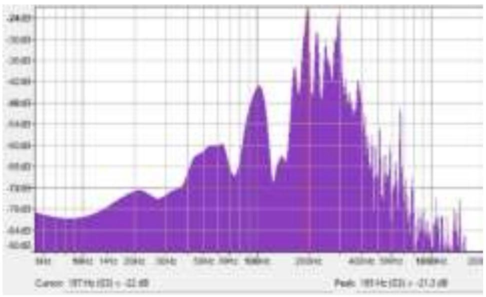
1. Below are the waveform, spectrogram and spectrum of a relatively well-behaved tongue playing a tone of 293 Hz (D4). You see the actual waveform, and under it the spectral content over the same time scale. One can see a dominant frequency (the yellow line) sustained for a long time. The spectrum graph shows a dominant peak and identifies it as 293 Hz, while other peaks are far weaker.





2. And here is a more complicated situation where a tongue is playing 193 Hz. Note the many loud peaks accompanying the desired tone, especially early in its duration. This is also reflected in the messier waveform.





To be clear, you don’t need all this sophistication to make a playable instrument... it’s a drum, not a Stradivarius. The common practice of relying on a tuner alone to get close to the right notes is OK too, and many builders don’t try even that. But I’m a physicist, and besides, did I mention that my grandson has absolute pitch?

Conclusions

Here are some lessons I learned from chasing after that G Major scale.

- The sounds produced are very sensitive to the progress of construction. The sounds made by the soundboard in isolation are different from those it makes when assembled onto the box; the sounds of a soundboard clamped to the box differ from those when it is glued to it; the addition of the bottom makes a difference, and adding rubber feet definitely improves the sound. Final tuning should therefore be done at the very end when everything is in place. On the positive side, if the drum sounds weak early in the construction, don't lose heart – it gets better as you progress!

- I got a nasty surprise after cutting the tongues: the long one became bowed, its "mushroom" end sitting lower than the others, and this mushroom was twisted (one edge lower than the other). This apparently introduced unwanted torsional vibration modes and made it sound clunky. The reason turned out to be that the jigsaw did not cut vertically around the mushroom – its blade leaned into the turn like a motorcyclist on a freeway! Further experiments with another jigsaw showed me that this is a common occurrence with these noisy tools, especially in thick wood; I had no idea, because I mostly use hand tools. I fixed most of the problem by removing material from below to make the mushroom edges more symmetrical. If I were to do it again I'd either use a scroll saw, or finish the mushrooms by hand, using a layout that leaves a wide gap above the tongues (start the gap by drilling, then widen and refine it with a rasp).
- The big block under the root side of the soundboard, seen at left in the next photo, is critical; it prevents the board from cross-feeding vibrations from tongue to tongue. Glue it well, but remove glue squeeze-out carefully – the tiniest bit at the root of a tongue can affect the sound.

- All gluing should be super solid, to prevent unwanted acoustic effects. I did get away with one cheat – I attached the bottom with screws rather than glue, to allow re-tuning.
- Tongue behavior is very sensitive to any change. For example, I had a good sounding tongue that needed a minor frequency tweak; I drilled a 1 mm deep hole under it with a ¼ inch forstner bit. This moved the pitch as intended, but the tone became very much worse, with spurious frequencies appearing out of nowhere. Yikes! What fixed this was easing the sharp edges of the hole, by using sandpaper to make it a bit more dimple-like. In general, rounded edges and curves seem better than pointy contours.

- I did not suffer from buzzing, but online resources suggest a well-positioned hole plugged by a dowel can make the buzz go away. As I said, every little change has unpredictable effects, some for the better, others not. Details are left to trial and error...
- One unexpected discovery: the human ear (or brain, I suppose) may not always hear what the spectrum plot shows. At one point I had a tongue produce two tones at identical amplitude, the desired high one and a spurious lower one, and the ear – mine and others I tested it on – heard only the higher tone.

And after weeks of this roller coaster ride, I had a fairly well-tuned drum; two layers of Ledicode polymerizing oil and it was ready to go. I must say, my neighbor had a point about the masochistic aspect of the project – the uncertainty of what the tongues will think to do next was rather stressful. But overall it was a wonderful adventure of wood and sound, and quite happily received by its intended player.

The finished drum, at last!

So, how does it sound? To be honest, I've heard drums from professional companies and experienced musical instrument makers that sound better; but among amateur creations, I think this drum holds its own rather respectably. You can make up your own mind watching these two videos, one showing the notes demonstrated in my own unskilled hands and the other playing a tune in those of my son in law, who is an experienced drummer.