Enhancing Guitar Tone through Precision Brace Trimming

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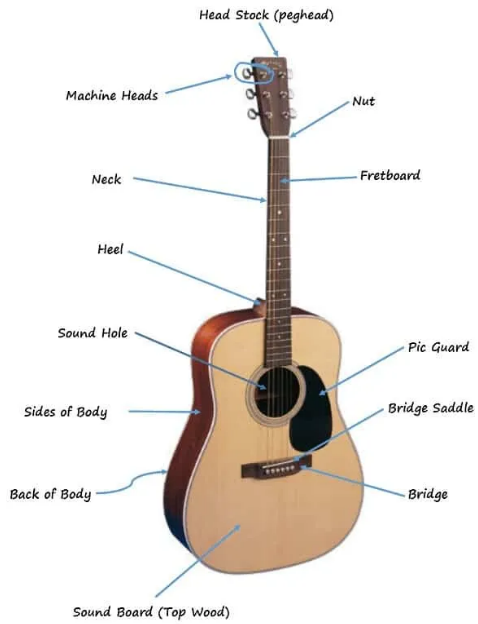
Table of Contents

Introduction

The quality of an acoustic guitar's sound and tone is affected by the material used to construct the top, back, and sides of the guitar, as well as the choice of strings used. The sound and tone of the acoustic guitar is also determined by the size, shape, and weight of the bracing structure underneath the wood top of the guitar. See example of bracing structure in Figure 1. Heavier or thicker bracing transmits a different sound than lighter or thinner braces. More bracing on the underside of the guitar allows for less movement from the top of the guitar and the soundboard. See labeled diagram of guitar construction and components in Figure 2. The thickness of bracing impacts the guitar's sound and tone. The strings and soundboard work together to produce the guitar's sound.

The soundboard's ability to produce tone is directly impacted by the type of wood and the grain of the guitar body, the characteristics of the bridge, and how the bracing on the underside is shaped and glued. "A good luthier will meticulously sculpt the bracing to give the guitar its "voice"" (Graphtech Guitar Labs). As the bracing structure ages and loses strength, the bracing may need to be re-sculpted and reshaped in order for the guitar to continue to produce a resonant tone. Our team's goal and research work focuses on building a prototype by which a guitar technician or luthier can re-sculpt the bracing without having to disassemble the guitar. The body of the guitar is glued shut during assembly, preventing the luthier from having easy access to the braces inside. The guitar must be fully assembled in order to conduct sound and tone analysis. When repairs are undertaken, the guitar is unstrung, unglued, disassembled, repaired, then reassembled, reglued, restrung, and tested again for sound and tone. This current method is a repetitive and difficult process that could be shortened in time and tedium through the use of a brace cutting tool that allows for repairs with the guitar assembled and strings in place.

A WPI IQP group from July 2020 looked at the possibility of making modifications to the bracing structure of guitars that have been completely built. That team designed a device that would be used to shave the bracing on an over-braced fully assembled guitar. Due to restrictions on access to labs and tools due to COVID, that July 2020 team was not able to build-out the design. Our team looks to expand upon that team's research by designing and manufacturing a brace cutting tool prototype with a similar function. Due to summer course time constraints, our team was not able to test our prototype on an assembled guitar. The next WPI team to take on this project can proceed to the prototype testing phase. The prototype testing will determine the feasibility, accuracy, cost, and efficiency of our brace cutting tool prototype design.

	
Figure 1: Guitar Bracing	Figure 2: Guitar Construction

Background

Once a guitar body is assembled, it is not an easy task to shape or sculpt the braces. Bracing repairs are complicated, even with the strings removed, because of the need to work inside of the closed guitar body. It can be tedious and difficult to access the bracing structure as the guitar technician or luthier can only do the work through the sound hole, an opening of about 4 inches in diameter or smaller. “Not only is it a cramped space, but much of the work must be done partially “blind”, while working through the sound hole. This can create problems such as over-trimming a brace or possibly shaving or sculpting the wrong brace accidentally. The nature of the task typically requires an array of lights, mirrors, inspection cameras, clamps, jacks, cauls, spatulas, etc.” (Guitar Repair Long Island). This repair work is thoughtful and delicate. The braces are soft and prone to denting under the pressure of clamping. Failure to properly support the guitar during clamping can cause damage to the guitar body. (Guitar Repair Long Island).

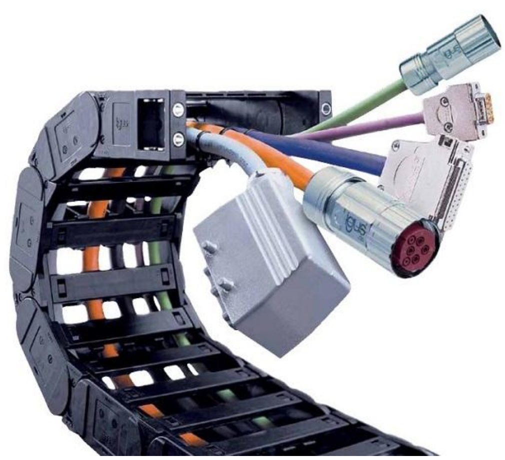
Developing a brace repair tool that can be placed through the sound hole and developing the requisite technology to support the tool’s functions to shave and sculpt a specific amount of bracing would be welcome advancements to luthiers, guitar technicians, and guitar players around the globe. Our team researched elements for a brace cutting tool design that would utilize abrasive wire and small electric motors. This design would include miniature cameras, i.e. endoscopes, and lighting attached to the wire and motor assembly. Our focus was to conceptualize a tool that would let the guitar technician or luthier accurately see and control their handwork. We also researched an alternative design of mounting a miniature circular saw at the end of an energy chain, to be discussed in the next section. We considered using other cutting methods, such as a small reciprocating saw and a dremel tool, but did not pursue these options due to size constraints of fitting the tool through the sound hole of the guitar.

Elements of a Brace Cutting Tool

Structure/Form Component

Energy Chain

The energy chain is the machine component to transfer cutting power and camera data through the guitar sound hole. An energy chain is a hollow chain composed of links that are flexible in one direction and rigid in the other directions. See Figure 3 for an example energy chain. For this application, the energy chain is used to pass the electrical power wires through the small sound hole in the top of the guitar. We anticipate that the structure and shape of the energy chain is small enough to allow entry through the sound hole with some or all of the guitar strings in place while cutting.

	
Figure 3a: Energy Chain Detail	Figure 3b: Energy Chain End Detail

Camera - Third eye

Videoscope

Cameras positioned on the energy chain allow the luthier or guitar technician to see inside the guitar while the brace cutting tool is in use. For our application, we are also considering the use of multiple cameras to be attached to the energy chain in order to give different viewpoints during the cutting process. Figure 4 shows a videoscope from AZO Materials, a company that manufactures videoscopes for use in the automotive industry. This product was specifically chosen because at the end of the wire, in addition to the camera and lights, an “opposable” extension, allowing free rotation and movement in order to view different angles of the cutting, is included.

Due to time constraints on this project, our team did not do further research on other possible videoscopes. We recommend research be conducted on cameras with intended uses in industries such as firearms manufacturing, medical and surgical, petrochemical, and power generation. These industries may also manufacture miniature cameras for use in areas or products with tight space constraints which could be utilized inside a guitar for precision brace cutting.

Figure 4: Automotive Videoscope

Types of Cutting Tools

To perform the brace cutting work, we reviewed a few cutting tool options: a Dremel tool, a circular saw, an oscillating saw. and an abrasive wire. Since our team is at the preliminary design and prototype testing phase of this research, we are unable to determine whether use of any of the following cutting tools allows for brace cutting with or without the guitar strings removed.

Dremel Tool (Sanding and Cutting)

A Dremel tool is a useful tool for guitar repair work and can be used for polishing frets, sanding, cutting, and grinding. For work inside of the guitar with entry through the sound hole, the Dremel tool is not an effective or efficient tool to use due to its large size, both in length and width.

Figure 5: Dremel Tool

Circular Saw

A circular saw might not be thought of as a guitar repair tool due to their size, however, circular saws are available in a wide range of sizes. Our team constructed and built a circular saw brace cutting prototype. We purchased a scaled-down miniature circular saw and attached it to a small motor. The saw blade was attached to the motor by a tapered cap that attached to the shaft of the motor. The circular saw and motor assembly was mounted with screws to the end of the energy chain. The motor was electrically powered by an external DC power supply. A switch was mounted at the top of the energy chain and controlled the operation of the motor. See Figure 6 to view the circular saw energy chain prototype.

A future WPI project team might consider mounting two miniature cameras next to the saw on the energy chain. One camera would be on the end of the energy chain to allow the luthier or guitar technician to see the location of the blade and how the blade is performing the cutting tasks. Then, a second camera would be located opposite to the first camera on a flexible arm. This second camera would allow the guitar technician or luthier to have a third person view of the cutting and repair work being done in real time.

Our team anticipates that this circular saw and motor assembly has potential as an interior guitar brace cutting tool. In order to operate the tool, the luthier or guitar technician would manually hold the top of the energy chain where the switch is located and have the lower part of the energy chain enter and descend into the guitar body through the sound hole. This method would give the guitar technician a free hand to accomplish the brace cutting work.

Figure 6: Circular Saw on Energy Chain Demonstrated by Chris

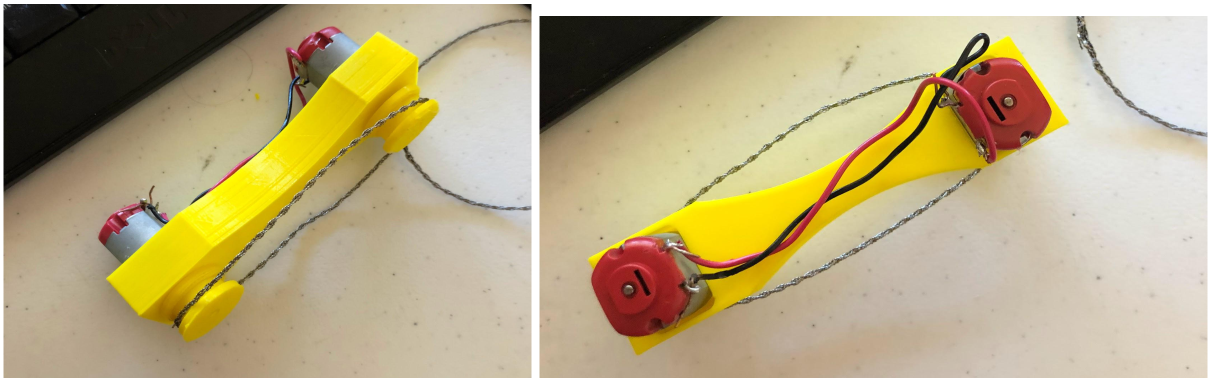
Oscillating Saw

We researched the use of an oscillating saw as another potential tool for internal brace cutting. An oscillating saw can be used for sawing, cutting, and removing large amounts of brace or other material while the guitar is open. The oscillating saw is a useful tool for a guitar technician or luthier to have in their tool kit, but, like the Dremel tool, the oscillating saw is too big and bulky to use through the sound hole in order to perform precision sculpting of any part of the bracing structure. There is not enough room for maneuverability by the technician within the closed guitar body through the sound hole.

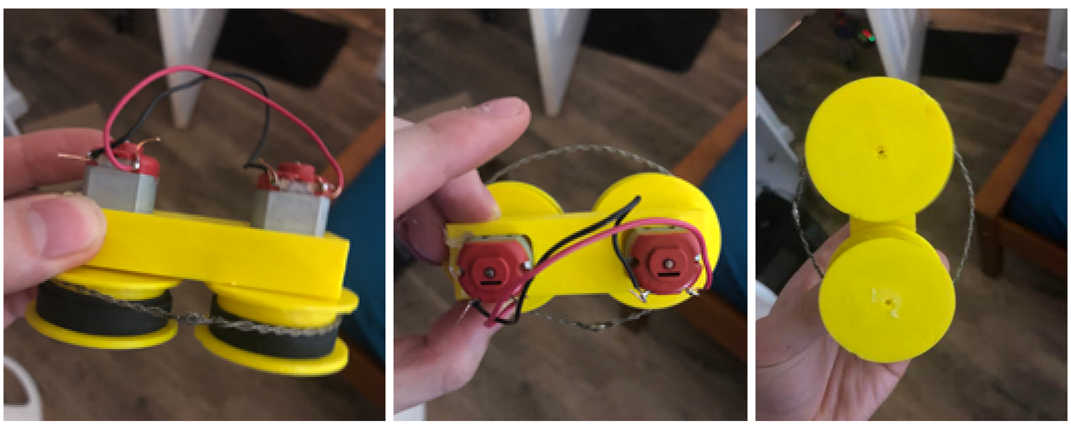
Figure 7: Oscillating Saw

Motorized Abrasive Wire

Another contender that we reviewed for the brace cutting tool was motorized abrasive wire. This type of wire is thin, maneuverable, and somewhat flexible making it a promising pick for cutting and sculpting braces within a confined area. Our team designed and built a brace cutting prototype with abrasive wire. See figures 9-13 for our team's wire saw prototypes. The abrasive wire method uses a set of co-rotating flywheels connected to two electric motors, all of which is mounted on an energy chain. The flywheels utilize rubber bands to hold the abrasive wire tight enough to spin, but with enough slack such that the motors do not bind up and stall. A switch positioned on the energy chain is wired to the motors of the flywheels. The head of the device is rather thick, gaining most of this thickness through the motors. Between the motors, there is a gap where the abrasive wire is located. This is the cutting section. We tested wires of different thicknesses and different abrasive grit levels. Issues encountered with each of the various wire types used were binding up of the wire, the wire being too loose or too tight, and difficulties in soldering the wire into a continuous loop. Another problem was found with a thinner gauge wire that was easier to solder together, but incapable of cutting into a piece of soft wood. During testing, the thinner gauge wire would either bind up against the wheels that held it on, or would not have enough kinetic energy to cut the wood. Our testing indicated that the wide design of the abrasive wire cutting tool head will likely provide a challenge to getting the cutting tool inside of the guitar through the sound hole without removing the strings.



Figures 8-9: Preliminary Wire Saw Prototypes



Figures 10-12: Second-generation Wire Saw Prototypes (narrower, with rubber bands. Soldering joint visible)

Interface Between Cutting Tool and Energy Chain

A mounting interface to attach the brace cutting component (i.e. circular saw, abrasive wire) to the energy chain can be researched and designed by the next WPI research team to work on this project. Our team utilized a low tech approach of merely drilling screws into the 3D printed piece that the motor is mounted upon.

Figure 13: Detail of Mounting Interface

Prototypes

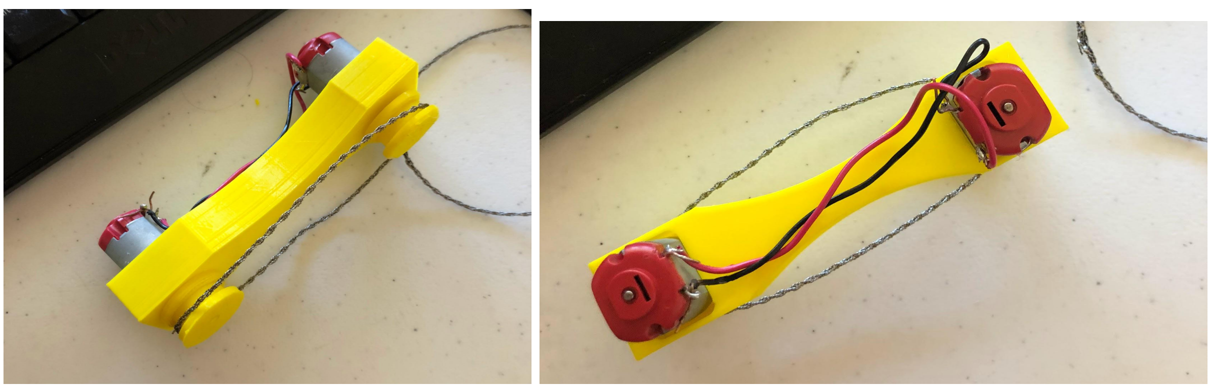
Energy Chain with Circular Saw

Use of the circular saw in conjunction with the energy chain will allow the guitar braces to be cut with entry through the sound hole with strings in place. The circular saw, however, does not perform well due to its limitation of cutting only in one dimension.

Figure 6: Circular Saw on Energy Chain Demonstrated by Chris

Wire Saw Prototypes

We designed two iterations of the wire saw cutting tool. Improvements from the preliminary to second generation prototypes included narrowing of the distance between the motors, inclusion of a rubber band on each flywheel, and improved soldering technique. The next WPI team to take up this project could research a method to firmly secure the two ends of the wire together in order to create a continuous loop. Such research and design work could lead to a working prototype for testing with a guitar.



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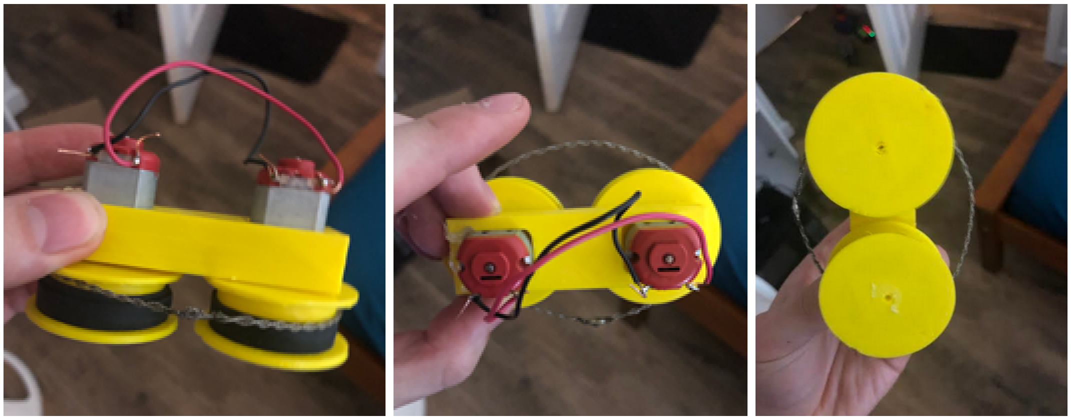

Figures 10-12: Second-generation Wire Saw Prototypes (narrower, with rubber bands. Soldering joint visible)

Conclusion

Although the project has been completed from an academic perspective, it still needs work done from a practicality perspective; such as further development, fabrication, and testing. Our team has progressed this project to the point where we have determined that the circular saw brace cutting tool and the abrasive wire brace cutting tool would each be a successful candidate for further development and testing. These two cutting tools each meet the goal of our project: designing a brace cutting tool that can be operated through the sound hole of an assembled and strung guitar. Both cutting tools can be controlled from a button at the top of the energy chain and can operate through the sound hole of a guitar.

Future Steps

Given more time, our team would have endeavored to continue design and fabrication of the abrasive wire cutting tool due to its ability to cut in any direction. Other future design work with the abrasive wire cutting tool would include the addition of cameras and lighting, the ability for flush cutting, and the drafting of protocols and operating procedures for training on the use of the tool.

For the cameras, emphasis on the plurality, there should be a camera on the end of the energy chain above the motor so that the guitar technician or luthier can see where to perform the brace cutting and can then cut with precision. Another camera on a set of helping hands for coarse adjustment would be a good feature. The cameras, in concert with each other, would allow the guitar technician or luthier to see what they are cutting while the cutting work is ongoing.

For flush cutting, the tapered cap was too tall, (see figure 13) and prevented the circular saw blade from cutting flush to the top of the guitar. This issue would be worthwhile for a future WPI project team to investigate and edit for future designs.

Finally, it would have to be investigated as to what training should be required for the guitar technician or luthier to learn how to operate the tool.

Our team's preliminary and second generation wire saw cutting tool, in hindsight, would have difficulty fitting through the sound hole due to the size of the motors. The third generation abrasive wire cutting tool, to be done by another WPI team, would want to utilize smaller motors. Such smaller motors will incur a higher cost to purchase but would fit through the sound hole.

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