Enhancing Guitar Tone through Precision Brace Trimming

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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 on the guitar. 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. 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, also known as the top wood, which 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, 1). 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. The team's goal and research work focus 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 during assembly, preventing the luthier from having easy access to the braces. 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, glued, restrung, and tested again for sound and tone. A repetitive and difficult process that could be shortened in time and tedium through the use of a tool that allows for bracing 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 on 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 similar prototype. Due to summer course time constraints, our team was not able to test the 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 design.

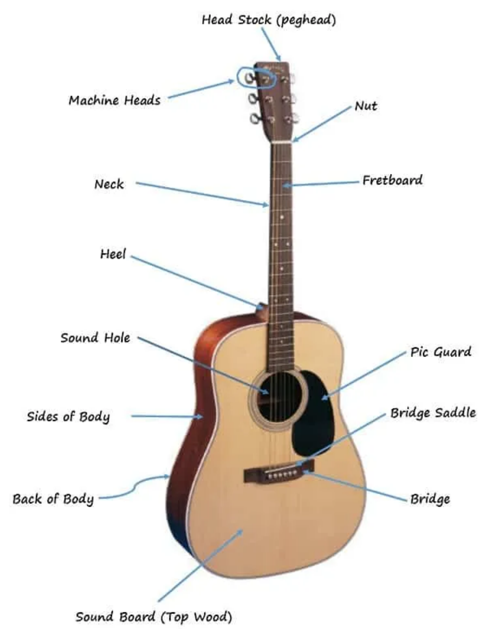


Figure 1: Guitar Construction

Figure 2: Guitar Bracing

Background

Once a guitar box is assembled, it is not an easy task to shape or sculpt the braces. Bracing repairs are complicated because of the need to work inside of the closed guitar body, even with the strings removed. It can be tedious and difficult to access the bracing structure as the guitar technician or luthier can only do the work through the soundhole, 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 soundhole. 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.

Elements of a Brace Cutting Tool

Structure/Form Piece

Energy Chain

The energy chain is the machine component to transfer cutting power and camera data through the guitar soundhole. An energy chain is a hollow chain composed of links that are flexible in one direction and rigid in the other directions. For this application, the energy chain is used to pass the electrical power wires through the small soundhole 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 soundhole with some or all of the guitar strings in place while cutting.

Camera - Third eye

Videoscope

Cameras positioned on the energy chain allow the luthier to see inside the guitar while the brace cutting tool is in use. For our application, we are also considering the use of multiple videoscopes to be attached to the energy chain in order to give different viewpoints of the cutting process. Figure 3 shows a videoscope from AZO Materials, a company that manufactures videoscopes for use in the automotive industry. This product specifically was 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 get 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 scopes 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 3: Automotive Videoscope

Types of Cutting Tools

To perform the brace cutting work, we reviewed a few options: a Dremel tool, a circular saw, an oscillating saw; and an abrasive wire. It is unclear at this stage of design and test whether use of one tool or another 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 sanding, cutting, grinding, polishing, drilling out stripped screws and hardware, and polishing frets. For work inside of the guitar with entry through the soundhole, the Dremel tool is not an effective or efficient tool to use due to its large size, both in length and width.

Figure 4: Dremel Tool

Circular Saw

A circular saw might not be thought of as a guitar repair tool, however, circular saws are available in a wide range of sizes. We purchased a scaled-down miniature circular saw and attached it to a motor. The saw blade would be held on to the motor by a tapered cap that attaches to the end 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. This configuration is external to the energy chain, however, it is worth noting that the power supply could also be located internal to the energy chain. Two miniature cameras would be mounted next to the saw on the energy chain. One camera would be on the end of the energy chain so that the technician can see the location of the blade and how the blade is performing the cutting tasks, while the second camera is located opposite to the first camera on a flexible arm. This second camera would allow the technician to have a third person view of the cutting and repair work being done in real time by the technician.

This circular saw and motor assembly has much potential as an interior guitar brace cutting tool as the luthier or guitar technician can manually hold the top of the energy chain where the switch is located and then have the lower part of the energy chain enter and descend into the guitar body through the sound hole while using the technician’s free hand to accomplish the brace cutting work.

Figure 5: Circular Saw on Energy Chain Demonstrated by Chris

Oscillating Saw

We researched the use of an oscillating saw as another potential tool for brace cutting. An oscillating saw can be used for sawing, cutting, and removing large amounts of brace or other material. 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 soundhole 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.

Figure 6: Oscillating Saw

Motorized Abrasive Wire

Another contender that we reviewed for the brace cutting tool was using 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.The abrasive wire method uses a set of co-rotating flywheels connected to high rpm, low torque 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. When the switch is on, the motors spin which then draws energy from a battery pack mounted at the top of the energy chain. 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 abrasive wire will likely provide a challenge to getting the cutting tool inside of the guitar through the soundhole without removing the strings.

Interface Between Cutting Tool and Energy Chain

A mounting interface to attach the brace cutting element (i.e. oscillating 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 7: Detail of Mounting Interface

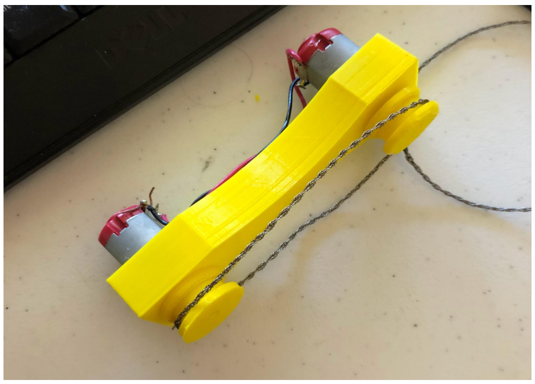
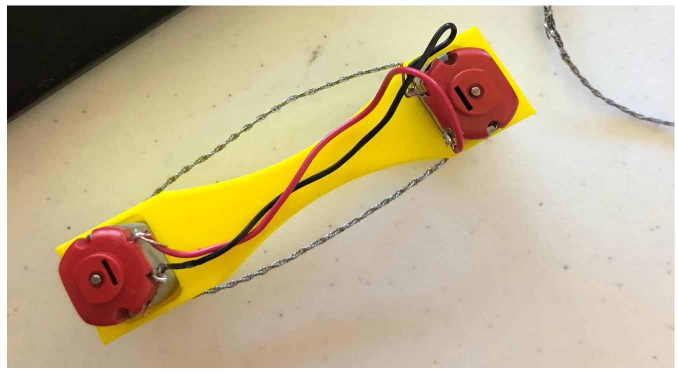
Prototypes

Energy Chain with Circular Saw

Figure 4: Circular Saw on Energy Chain Demonstrated by Chris

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

Wire Saw Prototypes

Figures 8-9: Preliminary Wire Saw Prototypes

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

We designed two models of the wire saw cutting tool. Improvements from the preliminary to second generation models included narrowing of the distance between the motors, inclusion of a rubber band on each flywheel, and improved soldering technique. The next WPI team might look to 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 would be instrumental in designing a third generation of this model for testing and could lead to a working prototype for testing with a guitar.

Conclusion

Although the project has been completed from an academic perspective, it still needs to be completed from a practicality perspective. With the project, progress has been made to the point where the device can be controlled from a button at the top of the energy chain and can fit through the sound hole of a guitar. However, there is still more progress that was desired to have been made. For what's next, there are a few items. The cameras, the flush cutting, and the training required. 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 luthier can see where they are cutting the guitar brace exactly, and then another camera on a set of helping hands for coarse adjustment. These in concert should be able to allow the luthier to see what they are cutting. For flush cutting, the bevel was too shallow, such that the dremel blade cannot sit flush with the top of the guitar, so that is something that should be edited for future designs. Finally, it would have to be investigated as to what training should be required for the luthier to be able to know where they should be cutting and how they are cutting in relativity to this. The wire saw, in hindsight, would not have been a viable method with the current setup because the motors would be too big to fit through the sound hole of a guitar. The dremel blade version is able to fit through the sound hole and is more precise in terms of location of where the cutting location would be.

References