MUSICAL INSTRUMENT DESIGN USING COMPOSITE MATERIALS

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Abstract: This paper discusses the investigation of composite materials in instrument building. Applications of epoxidized soybean oil in the context of instruments have been explored. A resin transfer molding setup has been constructed and provided preliminary samples for acoustic testing. Results are inconclusive for the effect of pre-tensioning and ESO use. Carbon fiber music strings have also been made and future applications explored.

Key words: composite, guitar, epoxy, bass, carbon fiber, additive

Introduction and Background

The technology of constructing musical instruments with epoxy resin matrix composites is still relatively new. Wood has traditionally been the composite of choice for many different instrument components. Wood's structure is limited though. For manmade composites, variation in the manufacturing process can result in a wide variety of material properties; as the part is crafted, the building material is also created. Differences in the manufacturing environment or techniques used will result in material changes, which aren't achievable with wood. Pre-tensioning of fibers is one manufacturing technique which will be discussed in this paper.

Instrument strings made of carbon fiber are commercially available, but limited. The sound produced by a music string is a function of their elastic constants, densities, and composite structures [1]. Modification of these properties, using epoxy additives, can produce strings with a wider range of sounds and applications.

The work discussed in this paper was a continuation of coursework in composites lab at the Rochester Institute of Technology. The course was project based; the project chosen was the construction of a carbon fiber 5-string banjo. The project was large, even for the two person team which was formed. It was completed after the course had ended, which was well into the next term. During the project: a lot was learned about composite technology, many opportunities for innovation were noticed, and questions were left unanswered. An independent study was the logical next step for this author. This paper is being written as a capstone to the independent study. But the work will continue.

Epoxy Additive: Epoxidized Soybean Oil

The additive discussed in this paper is epoxidized soybean oil (ESO). This additive is currently used as a plasticizer for plastic resins like PVC. ESO has yet to be utilized in many viable applications such as musical instrument construction. When added to epoxy it affects various mechanical properties, which include the following: increased vibration-damping, increased impact strength, decreased tensile strength, increased percent elongation at break and reduced hardness [2].

Damping of vibrations isn't desired in some musical applications such as guitar strings. But for violin strings, damping is desirable because the violin string must follow bowing action [1]. Carbon fiber violin strings are not readily available, and the use of ESO could change this. Currently available for violins are strings which have a core (usually non-metallic), that is covered in a metallic wrapping. Synthetic fibers, various metals and even sheep intestines are used to make strings. The use of ESO would allow for strings of differing properties to be made from the same materials (epoxy, fibers and ESO). The proportion of ESO to epoxy, and number of fibers could be adjusted to achieve the desired characteristics.

The research for applications of the epoxidized oil is limited though. And access to the additive itself is limited as well. A search to acquire experimental quantities of ESO did not result in the procurement of any ESO. For further research of ESO applications the search will start again soon with new leads.

Resin Transfer Molding

A Resin Transfer Mold (RTM) setup was constructed. The RTM was constructed to serve dual purposes: aid in the development of a new instrument and provide samples for acoustic testing. The resin transfer molding setup consists of an aluminum mold with a channel 0.500" wide, 0.040" deep and runs the whole 6" length of the mold (see Figure 1 in Appendix). Fibers are laid in the channel and grasped by clamps on either side of the mold. The fibers are then pulled in tension. The flat top of the mold is bolted on and the whole setup is encased in a vacuum chamber. Resin is then allowed to flow through a tube and into the mold.

Little quantitative data is available to evaluate the acoustic properties of composites in the domain of instrument building. The definition of a "good" sound is decided by the ear of an instrument builder, or player. Even an in-depth study of the building materials used in instrument making, such as the one conducted by Charles Besnainou [3], yields results still tainted by subjective terms.

The mold was constructed to provide bar samples, or panels, for testing. The natural frequency, among other factors, could be determined. The effect of different pre-tensions on the fibers could be measured. Also, the panels could be used in different configurations to experiment with creating a new type of instrument.

This mold has provided preliminary samples for testing. Future samples will be made to test different fabrication techniques. The variables that will be tested are limited to the following: fiber quantity, tension, and resin additives. Although the shape and size of a component has an impact on the acoustics, this will be held constant for all samples.

Music String Construction

Carbon fiber strings were constructed using 12k carbon fiber tow and West System 5:1 epoxy. They were made so they could be placed in a traditional stringed-instrument's tuning mechanism and tensioned. The carbon fiber is too brittle to be wrapped around a tuning peg though, so the first step in making the string involved bonding durable ends to them; a round wound bass string was used. The metal string portion of the composite is short so that when mounted, the metal is not within the playable span of the string. After the ends were cured, one end was fixed to a wooden structure five feet above the floor and the other end was fixed to a cantilever setup just above the floor's surface. When weights were added to the cantilever, the string would be pulled in tension. Carbon fiber is brittle, so it's difficult to find a section of tow without a few broken fibers. With this in mind, the strings were closely examined to find the location and nature of such imperfections. The epoxy was applied with the fingertips of latex-gloved hands; this made the manipulation of epoxy and imperfection compensation easier.

Strings were constructed using this method; of these strings, some achieved a good finish. The finish was smooth and glassy in appearance. A mounting frame was made for the strings; it consisted of a wooden frame and a guitar neck. After tensioning and playing the strings, it was determined that they showed potential. In the future a set of four strings will be made and strung to a bass guitar neck. After tuning them for the bass, a proper sounding board will be made of carbon fiber.

Conclusion

As newer technologies become more mainstream, they can create better solutions to previously solved problems. Composite technology has many unexplored applications; the limits are virtually endless for how this developing field can be applied.

Epoxidized soybean oil is currently used in industries other than musical instrument construction. If this additive can be properly applied to composite-instrument construction it could revolutionize the way instruments are manufactured. This requires further experimentation and awareness.

Manufacturing of the test panels resulted in preliminary tests. The results were inconclusive as far as the effects of per-tensioning and ESO use. The mold does provide consistent samples though. Having the mold will streamline further testing and allow the desired variables to be isolated.

The strings constructed show potential for use on acoustic instruments. When plucked, the sound they made was clear and strong. The proper introduction of epoxy-resin matrix composites into music string manufacturing could create drastic change in the process: increasing versatility and simplifying the process.

Appendix

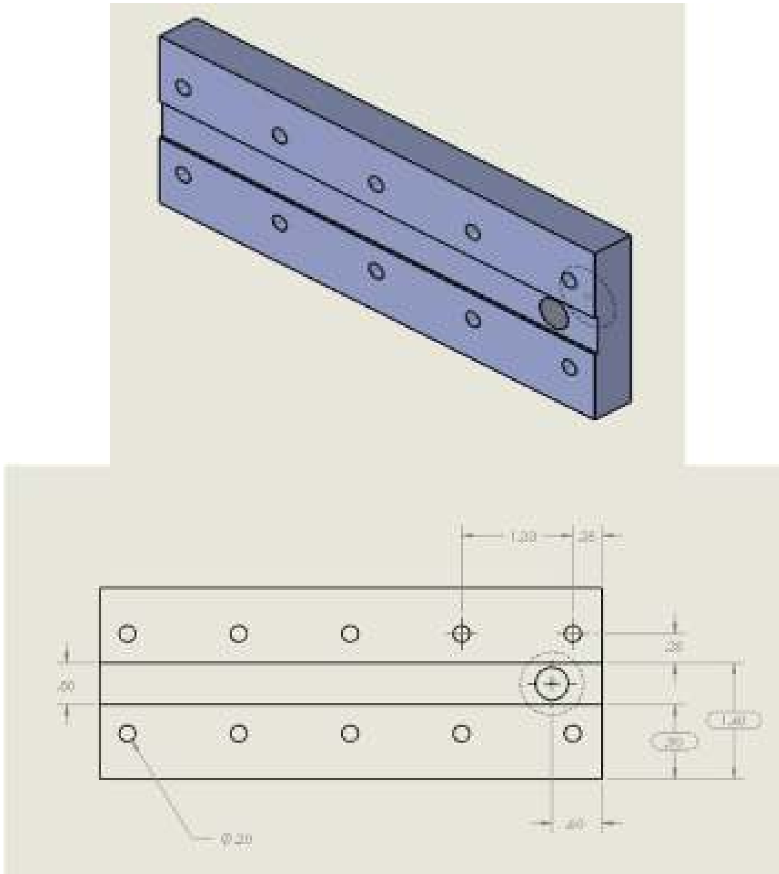

Figure 1: RTM design

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