CNC Milling Wood Patches in String Instruments Restoration

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Abstract

This article illustrates a typical work-flow for patch-making in string instruments restoration using CNC milling. This technique has many advantages over the traditional approach because it allows to restore complex shapes thus reducing the impact of the intervention. The process consists in four stages: manual preparation of the patch area, three-dimensional scanning of its surface, CNC milling of the new patch and its gluing to the instrument. Reported practical applications show how this procedure is less invasive and more effective than the manual.

1. Introduction

Manual patch making is an ancient technique. Restorers use it for several purposes: restoring the desired thickness maps, reinforcing cracks on areas weakened through time and rebuilding woodworm damaged areas. A very smooth surface has to be manually carved out with a simple outline (for instance oval shaped). Complex shapes such as those created by wood worms cannot be reproduced by hand.
On the other hand, 3D light scanning and CNC wood milling gives a replica of areas that cannot be reproduced manually, giving the conservators and restorers more leeway when planning their restoration work on wooden musical instruments. Due to an easier access to 3D light scanning and CNC milling technologies, more researchers and restorers can benefit from their use in daily work.

Figure 1: *Traditional patches*

Figure 2: *CNC milled Cello patch*

2. Materials and methods

Steps carried out in milling wood patches using a CNC router:

1. Surfaces preparation: areas to be replaced are manually excavated with gouges, planes and scrapers, in order to be patched
2. 3D light scanning of the surface or its replica (dental plaster or silicon)
3. CNC milling of the wood patch
4. Gluing, roughing and finishing

2.1 Preparation of the area to be patched

CNC technology has several advantages over traditional techniques; it not only adheres to the originality of the design but it is also less invasive as it reduces the impact of the first step (surfaces preparation). Once the patch is carved out, it is necessary to glue-size wood surfaces, whilst minimising the amount of water used which could cause deformations. Once dry, the surface is ready to go to the second step: three-dimensional scanning.

Figure 3 and 4 present a visual comparison on the different invasiveness of manual and CNC patching.

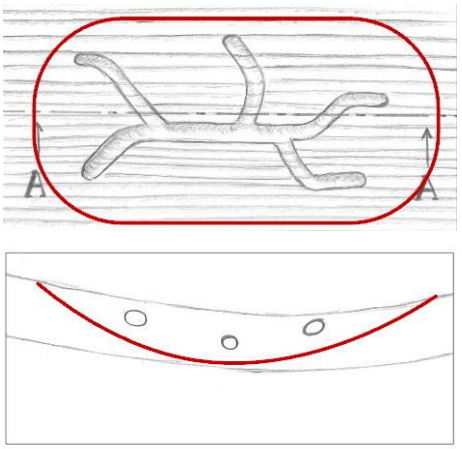

Figure 3: *Preparation for manual patch*

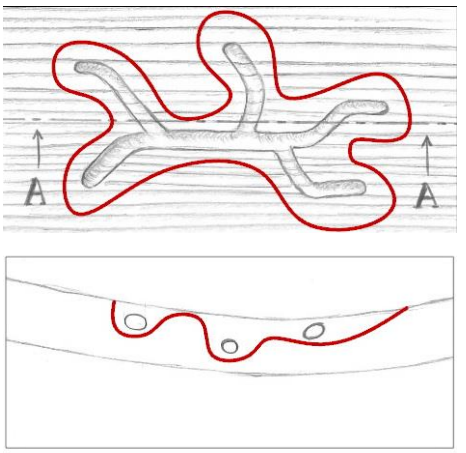

Figure 4: *Preparation for CNC-milled patch*

2.2. 3D light scanning

The second step consists in the digitalization of the patch area surfaces. The creation of the stl model is performed with a 3D light scanner either on the patch area or in its replica.
Scanning a dental plaster or silicon replica is usually preferred over scanning the original area: it is easier to move the replica to the scanning location instead of transporting valuable, delicate and rare string instruments. Moreover, plaster and silicone has greater dimensional stability compared to wood. This aspect is critical when the instrument part or its replica has to be moved to different environmental conditions: temperature and moisture content changes could affect the patch area dimensions and shapes. Finally, replica surfaces are more optically cooperative towards 3D light scanning: they are homogeneously light-coloured and non-reflective. Scanning directly the patch area wood surfaces can be problematic. Maple grain waviness, strong differences in colours between juvenile and late growth in spruce and maple can create artefacts in laser or in structured light scanning.

Figure 5: *Fringe pattern projected from a Structured Light 3D Scanner over a dental plaster replica*

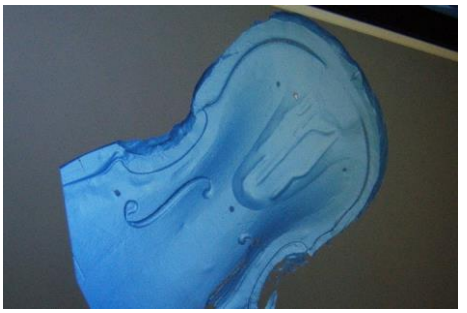

Figure 6: *Digital surfaces of the dental plaster replica, exported in Stereolitography (.stl) format*

The recent availability of high-precision and low-cost 3D light scanners and services make this technology an interesting tool for the violin maker and the restorer. Generally speaking, commercial structured light scanner are faster when compared to time-of-flight laser scanners, and offer enough accuracy for this specific application.

2.3 CNC Milling

Wood blank is chosen according to its anatomical features, in order to mimic the original material, in the same way that is performed with the traditional technique. CNC milling is usually performed with a 3-axis bridge vertical miller.

Care must be taken in order to keep the wood moisture content at a constant level. Changes in this parameter will affect shape and dimensions of the wood patch.

As an example, a 3% variation in the moisture content of red spruce results in a dimensional variation of about 1% in the tangential direction and 0.4% in radial direction [1].

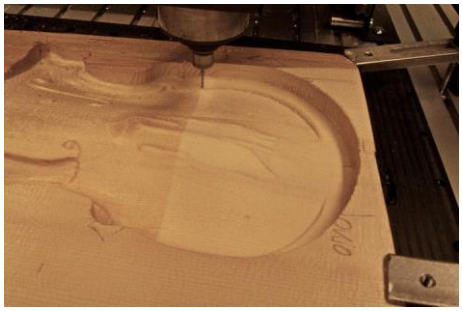

Figure 7: *CNC vertical milling of a violin top patch*

Figure 8: *Cello ribs through patch: at right the silicon replica, centre and left wood patches (courtesy Simeoni)*

Wood blank is fastened to the machine. A vacuum table can be used. A rough-pass is performed with a flat mill, for a fast material removal. Finishing is performed in several steps with ball mills of decreasing dimensions.

Wood surfaces are glue-sized before the final finishing step. A heat gun is used soon after glue-sizing, in order to speed the drying process and to avoid distortions.

This process can be repeated several times, in order to improve the surface quality and to saturate the wood fibres with glue.

2.4 Patch gluing

Gluing the patch to the original instrument requires both speed and precision in positioning the patch in its correct position. Usually CNC milled patch surfaces are quite complex and irregular, so that they fit in only one position. Additional positioning references such as studs or cleats can be applied over the instrument surfaces before making the replica. Both surfaces are already glue-sized. This shortens the time required for glue application, reducing the risk for the glue to gel. A warm ambient temperature help ensuring adequate fluidity of hide glue in this delicate phase.

3. Examples

String instrument tops and backs, together with their plaster casts, can be vacuum bagged. That means that a thin plastic film is wrapped around the plate and its mould, and vacuum is applied [2]. Plate surfaces adhere perfectly to the dental plaster mould, and the presence of plastic film allows a replica of the internal surface of the plate. Arching corrections is performed modifying the plaster cast shape (see Figure 9), moistening and pressing the plate with hot sandbags against its cast. A large patch needs to be applied to the plate, in order to fix this correction. Traditionally this patch is hand carved and fitted pressing the plate against the modified cast. Process is obstructed by the plate spring-back and the difficulty in keeping the plate homogeneously pressed to the cast.

Great improvements in therms of speed and precision can be achieved vacuum bagging the plate to the modified cast, creating a plaster replica of the patch area surface and CNC milling the wood patch. An example of internal plaster cast set-up is reported in Figure 10. Note the film wrapping both the cello back and its plaster modified counterform.

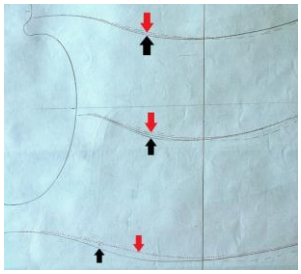

Figure 9: *Arching corrections of a cello back. In red, the final state*

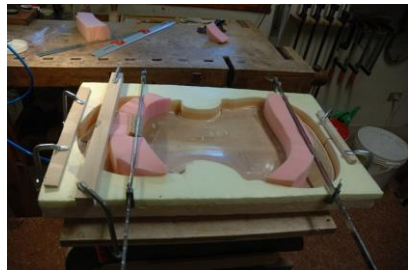

Figure 10: *Preparing the dental plaster replica of the internal surface, vacuum bagging the back and its cast aft arching corrections (courtesy Simeoni F.)*

Another example of the various steps of CNC patch making is reported in Figure 11: at top the violin belly ready to be patched. At bottom left its plaster cast (made with vacuum bagging). At right its carved wood patch. Patch 3D scanning and CNC milling for this specific violin are shown in Figure 5, 6 and 7.

The restored violin top is presented in Figure 12. Here the CNC patch is used also for edge doubling of the centre and upper bout.

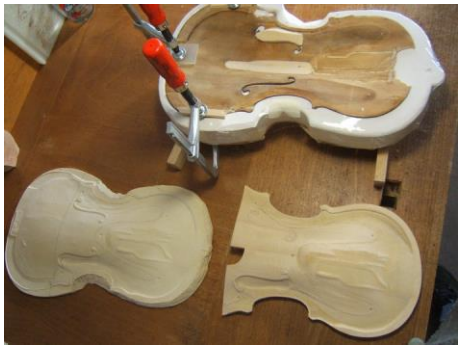

Figure 11: *three stages in CNC patch milling: bottom left the dental cast, at right the milled wood patch*

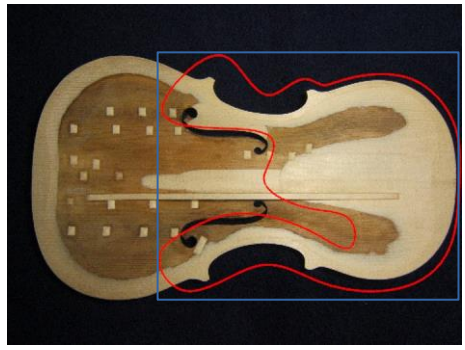

Figure 12: *The finished work. CNC patch is inside the red area.*

4. Conclusions

A variety of technologies such as 3D Solid Modellers, 3D Optical Scanners and CNC milling machines have become part of the tools available to the restorer. They made possible performing restoration tasks otherwise too complex, expensive or even impossible.

They provide more effective, quick and less invasive restoration than traditional techniques. They can be joined to the latter to expand the range of possible solutions to the restorer's daily problem.

Acknowledgments:

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References

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