SFSA Cast in Steel 2025 - George Washington's Sword

Technical Report

University of Wisconsin-Madison - Blazing Badger Bladesmiths

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Executive Summary

We created a replica of George Washington's silver lion-headed cuttoe, the sword he likely wore during his famous crossing of the Delaware River. This sword was chosen mainly because it appeared to be amenable to casting and had a unique lion head pommel that added to the interest of the piece. It was also decided to cast the blade of the sword, and add the handle components as separate pieces.

When designing the blade, all dimensions and proportions were taken directly from either the silver lion-headed cuttoe itself or from measurements of similar historical swords. This was done in an effort to not only create a functional product, but to make a sword that would have been able to be used in the context of Washington's time. Once a model was made, four sword blades were 3D printed in preparation for casting.

The alloy used for the sword was 17-4, a precipitation hardening stainless steel. This alloy was chosen because the precipitation mechanism used to harden it had essentially no risk of distorting the long, thin castings, unlike a more traditional quench and temper process, despite resulting in slightly lower hardness. It also produces a very tough microstructure that is less likely to fracture.

We chose to cast the blades using the investment casting process, as its excellent dimensional stability and surface finish allowed us to cast the blades very close to their final dimensions. The 3D printed swords were attached to a wax gating system, coated in ceramic slurry, and melted out in order to create the molds. All four castings came out reasonably well, and the best casting was selected to use for the final product. Heat treatment of the castings involved a solution anneal followed by aging to form precipitates. After heat treatment, the blade was ground to its final shape with a belt grinder.

The handle construction consisted of a hidden through tang. The guard, handle, pommel, and knuckle chain were all made by hand using tools and techniques similar to what would have been available in George Washington's time. The handle was made from a locally acquired material, as on the original sword it was made with locally sourced animal bone rather than imported ivory.

The finished sword is 35 inches long with a 29.75 inch blade. It weighs about 2 lbs. Aside from the cast 17-4 stainless steel blade, it consists of a hand forged mild steel guard and pommel, a white ash handle, and a copper knuckle chain.

Introduction

SFSA has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available. We at the University of Wisconsin-Madison partnered with MetalTek International and ThermTech to produce a replica of George Washington's silver lion-headed cuttoe. This sword is of great historical significance, as it was probably the sword Washington carried at the start of the Revolutionary War, and may be the sword he had with him during his famous crossing of the Delaware River [1].

Design

There are several reasons why we chose to make a replica of the silver lion-headed cuttoe, as opposed to one of George Washington's other swords. First was its curved, sabre-like profile. This shape meant that we did not have to worry about keeping the profile perfectly symmetrical, as would be needed for a straight sword. If the blade were to warp or otherwise deviate from its intended profile, it would be much less noticeable and easier to work with if the blade was curved anyway. In addition, the thick, well-defined spine of the blade made this sword appear to be more amenable to casting. Finally, the pommel in the shape of a lion head seemed like it would make the final product more interesting than a more standard handle.

Next, it was decided that we would cast the blade of the sword, and the crossguard, handle, and pommel would be added as separate pieces as in the traditional method. This simplified the casting process and potentially eliminated any problems that could arise from casting a part with a nonuniform thickness.

When making a 3D model, the profile of the blade was based off of online images of the silver lion-headed cuttoe. Some key observations included that the curve of the blade is not a single arc, with most of the curvature occuring at a certain section along the length of the blade. Another was that the width of the sword tapers toward the tip. The thickness of the blade was based on the dimensions of historical examples of similar swords. These dimensions were rounded up slightly to ensure that the mold of the blade would completely fill with metal. The thickness of the sword is also tapered toward the tip. A final detail that was added was to ensure the junction of the tang and the blade had a small radius rather than being a sharp corner, which could act as a stress concentration. The 3D model can be seen in figure 1.

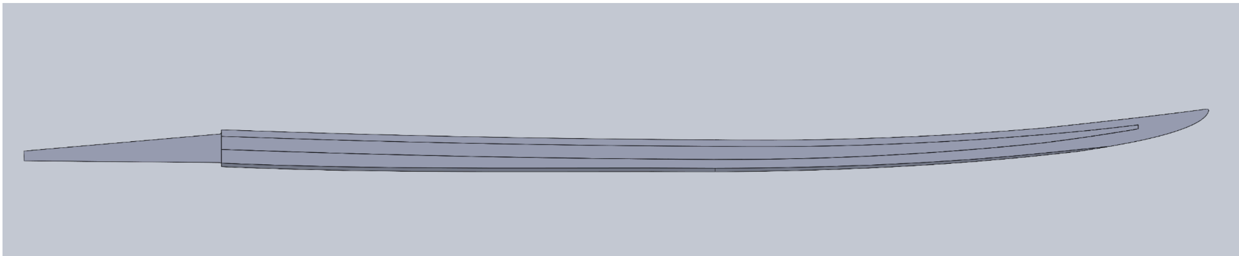

Figure 1: 3D model of the sword blade.

Alloy Selection

A key concern with this project was that the sword blade, being very thin, would be prone to warping during heat treatment. To avoid this problem, we decided to use a 17-4 stainless steel alloy. This is a precipitation hardening alloy, and the formation of the precipitates that strengthen the alloy results in much less residual stress than a traditional quench and temper process. As a result, there was very little risk of the blades warping during heat treatment. This alloy is also very tough, so the sword should be able to withstand abuse without snapping.

The only trade-off was that this alloy does not get quite as hard as a traditional quenched and tempered carbon steel, but it still achieves a hardness that should be sufficient for reasonable edge retention and is consistent with historical examples. The expected hardness was around 45 HRC.

Casting

The sword blade was made using the investment casting process. Investment casting's excellent dimensional stability and surface finish allowed us to cast the sword blade very close to its final dimensions. It is also a process our foundry partner, MetalTek International, is very well equipped to handle.

This process began by 3D printing four sword blades. They were printed out of pure PLA without any coloring or additives. Each blade was printed in four separate pieces, which were then glued together with the help of alignment pins.

With MetalTek's help, the PLA swords were attached to a wax gating system. This can be seen in figure 2. They were then coated in multiple coats of a ceramic slurry, as seen in figure 3. The wax and PLA was burned out, and the molds were preheated for casting.

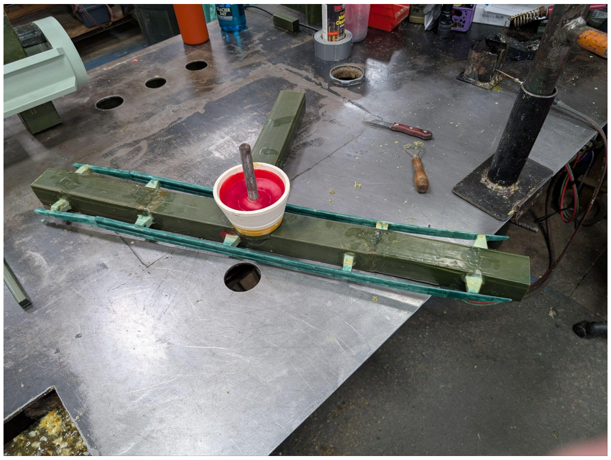

Figure 2: Wax gating system.

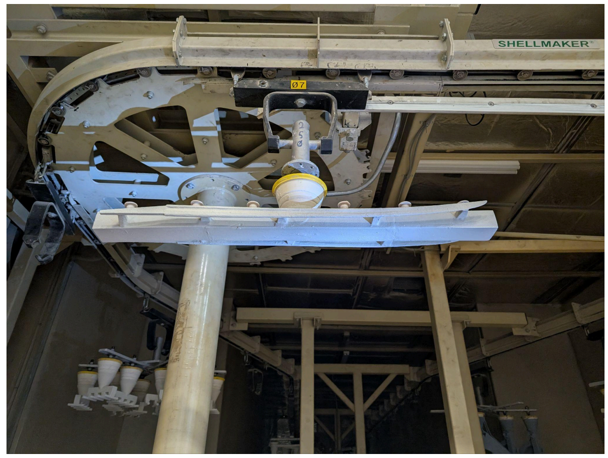

Figure 3: Gating system with first coat of slurry.

All four castings came out reasonably well and could have produced usable swords. The tips of three of them had some trouble filling, and some had small ceramic inclusions in their tangs. However, one of the castings came out perfectly, and this one was used to make the final product. The four castings can be seen in figure 4. Each casting weighed about 2 lbs.

Figure 4: The as-cast sword blades.

Heat Treatment

We worked with a local heat treatment company, ThermTech, to heat treat the swords. The swords were first solution annealed at 1900℉ for about 30 minutes and quenched to room temperature to form a low-strength martensite that is supersaturated with copper [2]. After this stage, the swords were straightened to remove warps that were picked up during the casting process.

Next, the swords were hardened by aging at 900℉ for one hour. This resulted in the precipitation of a copper-rich phase from the supersaturated matrix, strengthening the alloy [2].

Post Processing

A belt grinder was used to clean up the profile of the blade, grind away some slight warps, and reduce the thickness of the blade. The bevels of the sword were also ground in, as they were excluded from the design phase to insure that the mold filled completely during casting. The tang was only ground as much as was needed to get the handle components to fit. While the sword was being ground, it was frequently submerged in water to prevent overheating. Overall, there was not much grinding that needed to be done, as the sword blade was cast very close to its final shape.

After grinding, some spots, particularly the fullers, were touched up with some hand sanding. The final edge was put on the blade with a sharpening stone, though the third of the blade nearest the handle was not sharpened as much. This is consistent with historical examples, as this part of the blade is not an important cutting surface. The finished sword was coated in mineral oil to prevent rust.

Handle Construction

The handle consisted of a hidden through tang, with the guard, handle, and pommel of the sword being separate pieces that slid onto the sword's tang. The separate pieces laid out can be seen in figure 5. The tang extended through all the pieces, and was riveted over the pommel to permanently secure the pieces. Epoxy was also used to fill in any gaps as well as to provide a secondary method of attachment.

The guard and pommel were hand forged from mild steel. Holes were punched in each piece and were drifted to the approximate size and shape of the tang. Afterwards, the pieces were annealed. They were heated to fully convert to austenite, then buried in clay to slowly cool. The oxidized surface was removed with a combination of filing and soaking in vinegar. Since the pieces were softened from the annealing cycle, designs were able to be stamped in with several differently shaped chisels. To mount the knuckle chain, a hole was drilled in the guard and a copper loop was soldered onto the pommel.

The handle was made out of two pieces of wood. A perfectly flat surface was planed and sanded onto each piece, and a recess was carved into one of the faces to fit the tang. The two flat faces were then glued together, forming one block of wood with a hole for the tang. The handle was then carved to shape with a drawknife and spokeshave, and a coat of linseed oil was applied as a finish. The wood used was white ash, which is a wood native to Wisconsin that was acquired locally. This is appropriate for this sword as the handle of the original was made out of local, American-sourced animal bone, rather than the more typical imported ivory [1].

The knuckle chain was made out of copper wire and was attached after the rest of the handle pieces were attached to the blade. An image of the completed handle can be seen in figure 6.

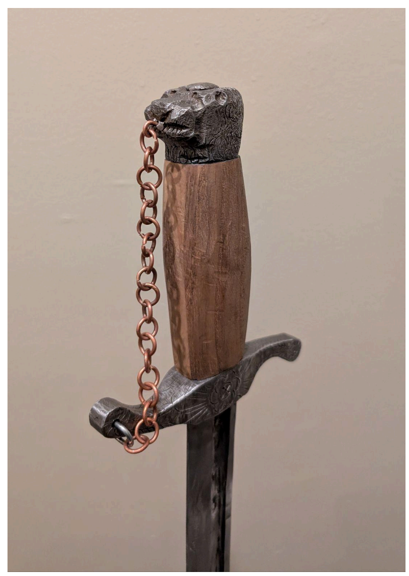

Figure 5: Tang extends through all handle components. Figure 6: The completed handle.

Final Results

The final sword was 35 inches long with a 29.75 inch long blade. The blade by itself weighed 1.25 lbs, and the weight of the completed sword was about 2 lbs. The hardness, taken on the tang of one of the sword blades, was 40.1 - 43.8 HRC, a little lower than expected. The sword was able to cut through apples and celery with ease.

References

[1] "George Washington's Mount Vernon." *George Washington's Mount Vernon*, Mount Vernon, 2025, www.mountvernon.org/preservation/collections-holdings/washingtons-swords/the-silver-lion-headed-cuttoe. Accessed 21 Mar. 2025.

[2] Dossett, Jon L, et al. *ASM Handbook. Volume 4D, Heat Treating of Irons and Steels*. Materials Park, Oh, Asm International, 2014.