

SFSA Cast In Steel 2026 – Horseman’s Axe Technical Report

Georgia Southern University – Partners in Crime



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1. Introduction

This is the report documenting the creation of a horseman's axe at Georgia Southern University for the 2026 Cast in Steel competition. SFSA has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available.

An axe is a wedge-shaped blade affixed to a shaft at a right angle. Axes have been in use as tools since approximately 6000 B.C.. [1] Used for as both tools and weaponry, the axe has been made from stone, bronze, iron, and finally steel following the material developments of the age. The use of combat specific axes can be traced back to roughly 500 A.D., with the adoption of the throwing axe known as the Francisca by the Franks (Figure 1). As armor technology improved, axe geometry began to shift to better accommodate the improvements. Blades became thinner and began to take the crescent shape and rearward facing spikes were added to penetrate plate armor. [2] A horseman's axe is a one-handed cavalry axe consisting of a wooden or steel handle and an axe head with a curved pick facing opposite the axe head. An example of a "typical" horseman's axe is shown below in Figure 2.



Figure 1. Francisca throwing axe [2]



Figure 2. A typical horseman's axe [3]

2. Design

2.1 Axe Design

The axe was designed to be lightweight for easy one-handed swinging, suitable for use on horseback. The total weight of the assembly is 2.73 lbs. A 6" half-circle/crescent blade, 0.25" thick in the center and tapering down towards the edge was connected to an elliptical mounting eye with dimensions 1.25" x 1.00". A tapered and fullered pick, 5" in length extends opposite the blade. The pick is slightly curved downward to help make contact during a swing. The axe was left simple in design to utilize hand engraving for artistic expression. A 24" hickory handle was used for its straight grain and impact resistance. The author's family crest was engraved on one side of the blade and other designs important to the life of the author were placed throughout the axe head.

The handle has a leather wrap placed on the end with thicker sections above and below the handle to prevent sliding of the hand off of the handle.

2.2 Alloy Selection

A proprietary steel that was custom-designed for ground-engaging tools application was selected because of its combination of great hardness, strength, toughness, and work hardenability. Our foundry partner, Carolina Metal Casting, pours this steel for a variety of components. The target composition of the steel is 0.3C-1.1Mn-1.6Si-2.1Cr-0.51Ni-0.32Mo. This metal is typically heat treated at an austenitization temperature of 1688°F followed by agitated oil quench and tempering at 392 °F. The expected properties of this steel after heat treatment are 52 HRC hardness, 252 ksi tensile strength, and 15 ft-lb impact toughness at room temperature. The actual composition and properties were tested in our university's labs and can be found in section 3.8.

2.3 Gating and Riser Design

Due to the small size of the axe head and the desired surface finish, investment casting was chosen as the molding process. The use of a large central downsprue greatly reduces the need for risering of the casting and the preheating of the shell helps with filling thin features such as the rearward spike. To produce a quality axe head, proper filling and directional solidification was desired to prevent unnecessary turbulence, porosity, and unfilled features. Filling and solidification simulation was performed using Magma 6.1. A gating system/tree was designed as shown in Figure 3 and simulated. The large central downsprue acts as a riser and promotes directional solidification from the thinner axe head into the sprue. To verify this, the fraction liquid result was evaluated. The last section of the axe to solidify is shown in Figure 4. The gates remain liquid until after the solidification of the axe, allowing continued feeding of the final section to solidify. Due to concerns of oxide inclusion formation, a filling velocity of less than 1 m/s was desired. The filling velocity result was evaluated to verify that flow into the axe remained below this threshold. Due to the height of the downsprue and acceleration due to gravity, velocity is above the threshold when making initial contact in the base of the sprue but by placing the ingates 1 inch above the base of the sprue a smooth, lower velocity flow was seen in the ingates resulting in a smooth filling of the axe. The velocity result with a threshold of 1 m/s is shown in Figure 5. Vents were added to prevent air pressure buildup and placed on all corners and the highest location of the casting.

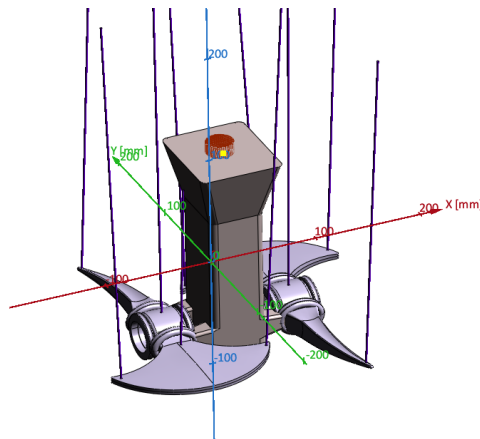


Figure 3. Casting geometry used in simulation

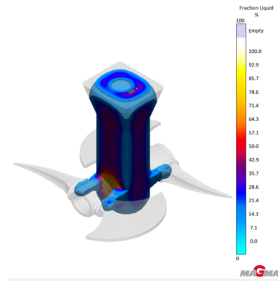


Figure 4. Fraction liquid showing the directional solidification into the sprue preventing porosity formation

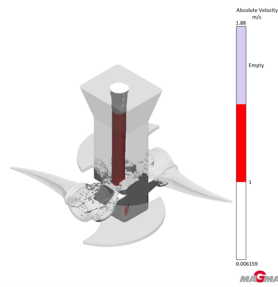


Figure 5. Velocity result from magma simulation showing smooth filling, less than 1m/s entering the axes

3. Manufacturing

3.1 Pattern and Shell Production

The investment casting pattern was produced using FDM 3D printing on a Bambu X1 Carbon and printed with a layer height of 0.2 mm. A low-ash PLA filament was used to prevent inclusions in the final casting. The pattern was sanded and smoothed using isopropyl alcohol to remove layer lines. Following smoothing the pattern was assembled using alignment pins and super glue. Gaps were filled with wax and wax wire vents were placed on the simulated location. The completed pattern is shown in Figure 6.

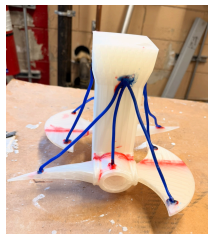


Figure 6. Investment casting pattern prepared for shelling, with vents added

Following production of the pattern, the patterns were dipped in investment slurry. The slurry used is a water-based, fused silica investment slurry. The trees were coated with two zircon-based prime coats and six fused silica-based backup coats. This gives it enough strength to withstand burnout and prevent cracking during pouring and the solidification process. The plastic patterns were burned out using a propane torch and the shells were fired at 1562 °F for 1 hour before being allowed to cool in the furnace overnight. The shells were then cleaned of any debris before being preheated to 1652 °F prior to the metal being poured. The completed shells are shown in Figure 7.



Figure 7. The liquid metal being poured into the assembled mold

3.2 Casting Process

The axe head was cast in-house at the Georgia Southern University foundry. The steel was melted in a 100-lb induction furnace under argon atmosphere and killed with aluminum during tapping. Molten steel was tapped at 3,150 °F and poured at an estimated 3000 °F. All personnel followed safety protocols to ensure a safe and efficient pour. Prior to tapping, investment shells were preheated to 1652 °F, removed from the furnace, and placed on the pouring line. Immediately after placement on the pouring line, molds were poured. Following pouring, the castings were allowed to cool in mold overnight. Figure 8 shows the final casting after the casting had cooled.



Figure 8. The final casting after being removed from the tree

3.3 Heat Treatment Considerations

After casting, the axe was normalized by austenitization at 1700 °F for 1 hour followed by air cool. This normalization cycle was to homogenize the as-cast grain structure, relieve the internal stress, and refine the grain sizes. Finally, the axe was directly austenitized at 1700 °F for 1 hour, then quenched in non-agitated oil. A metallographic image (Figure 9) of a section of the sword shows the sword is fully martensitic. Finally, the

axe was tempered at 400 °F for 60 minutes. This is to precipitate fine carbides from the martensite, forming a tempered martensite microstructure in the sword blade. Tempering time was selected by comparing the hardness and Charpy analysis of the cast steel samples prepared from the heat.

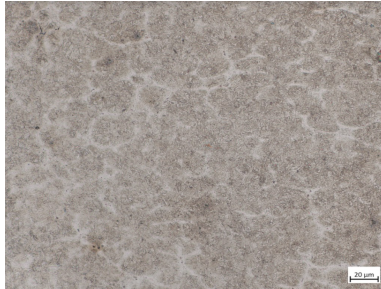


Figure 9. Microstructure of quenched axe showing fine lath martensite

3.4 Post-Processing, Handle Preparation, and Final Assembly.

Prior to heat treatment, vents and gates were ground flush with the casting surfaces and the axe was shot blasted and sandblasted. The axe was heat treated and then shot blasted and sand blasted again. The edge was beveled and then the entire axe was coated in spray primer. Designs were embossed on the axe surface using a hand embossing tool. The axe head was then submerged in salt water and exposed metal surfaces were etched using electrolytic etching. The etched surfaces were blued using bluing compound for greater contrast and the primer was removed. The axe head was then stonewashed using a vibratory polisher and sharpened. The handle was made from a premade sledgehammer handle. The handle was sanded, won, had decorative patterns wood burned, and was stained. 1/8" thick leather sheets were cut and stained to create the handle bound and tacked onto the handle. Leather cord was then wrapped to create the grip. The head was then placed on the handle and wedged into place. The fully assembled axe is shown in Figure 10.

Commented [MX1]: ??



Figure 10. Assembled axe for the competition

3.5 Testing

The steel chemistry was measured with an optical emission spectrometer and a Carbon/Sulfur combustion analysis machine. The chemistry measured is listed in Table 1. The chemistry shows lower manganese and nickel than desired but otherwise meets the specifications for our modified 8630 steel.

Table 1. Composition (wt. %) of the steel

wt. %	C	Si	Mn	Cr	Ni	Mo	Al
Target	0.30	1.60	1.10	2.10	0.51	0.32	0.02
Actual	0.38	1.49	0.88	1.90	0.39	0.33	0.02

To achieve the optimum combination of hardness and toughness, the software JMatPro was used to calculate hardness and charpy impact energy at varying tempering temperatures. After analyzing both graphs, the team determined that tempering at 400 °F (204 °C) for 1 hour. The temperature and time were chosen to ensure the axe was fully tempered to achieve the desired combination of hardness and toughness. Figure 11 shows the hardness versus tempering temperature. Figure 12 shows the charpy impact energy versus tempering temperature.

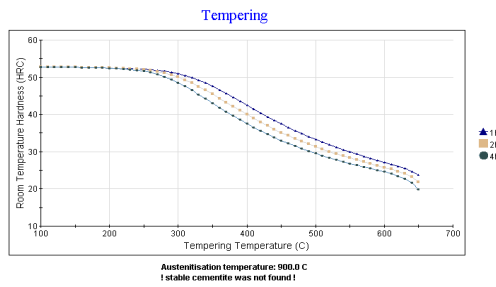


Figure 11. Room temperature hardness versus tempering temperature

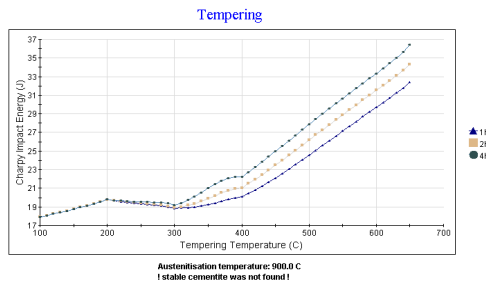


Figure 12. Room temperature hardness versus tempering temperature

The axe was tested by the student team by slicing and stabbing an assortment of steel drums, ice, wood, and fruit to simulate how this axe could have been used and to test the sharpness of the blade. No damage was to the spike or edge was seen after testing.

4. Executive Summary

The 2025 Cast in Steel competition, organized by the SFSA, aims to encourage students to explore the casting process and apply modern technology in creating steel products. Our team from Georgia Southern University designed and manufactured a horseman's axe capable of surviving testing and performing the desired puncturing and cutting actions.

Historical Background and Accuracy

The horseman's axe, a small one-handed axe with a rearward facing spike was commonly used following the development of steel plate armor. Used mounted, on horseback, the horseman's axe thin crescent shaped blade and spike are designed to puncture surface hardened plate armor and pierce the opponent. While this design is aimed to be historically accurate in geometry and sizing, the engraving. The engraving on the surface, is not perfectly accurate

Design Process

The axe was designed to perform on horseback with single-handed use. Proven handle construction methods were used to ensure durability even through extreme testing. Extensive simulations using Magmasoft optimized the gating design to ensure a high-quality, sound casting with minimal porosity and inclusions. Extensive post-processing was performed to meet the author's artistic standards.

Final Results

The final axe measures 24 inches in length and weighs approximately 2.7 pounds. The axe is made from a proprietary steel alloy (0.35C-1.60Si-1.01Mn-1.99Cr-0.38Ni-0.33Mo) chosen for its hardness, strength, and toughness. The handle is produced from straight-grained hickory wood to ensure sufficient durability for use. The axe head underwent significant heat treatment, including normalization, quenching, and tempering, to achieve a tempered martensite microstructure, ensuring optimal performance. Testing confirmed the axe's sharpness and durability, meeting all competition requirements. Engraving is an expression of the author's self and pays tribute to the author's family heritage.

In conclusion, the axe is a tribute to the author's family and is an artistic expression of the author himself. Through proper design, the axe can efficiently perform required tasks due to optimized geometry. This project greatly helped the team to learn about the use of casting process to add value and the steel casting process.

5. References

[1] Sydney Anglo (2000), *The Martial Art of Renaissance Europe*. New Haven and London. Yale University Press. p. 150

[2] Moore, Joe (2019), Francisca, <https://www.wiltshiremuseum.org.uk/news-articles/artworks/francisca-throwing-axe/>

[3] McPeak, William (2011), “The Battle Ax”, <https://warfarehistorynetwork.com/article/the-battle-ax/>