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

Georgia Southern University – Southern Steel Company

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1. **Introduction** (The Met, myArmory.com)

A horseman's axe is a revolutionary combat weapon primarily developed to counteract the usage of revolutionized high-quality plate armor. Dating back to as early as the 14th century, a horseman's axe, as the name suggests, is intended to be wielded by a horseback rider using only one hand. Having both brute force and secure integrity throughout, this axe was unlike anything seen before. The kinetic energy concentrated with each blow made quite an impact. If the axe didn't penetrate defensive armor, it was more than likely to wreak havoc on whatever was on the other side of it. In spite of the weapon becoming nearly extinct after the development of gunpowder, the once artillery staple will always be recognized as a weapon of industrial development and a sentiment to those who fought for what they believed in.

Figure 1. A medieval replica of a horseman's axe housed in Spain's *Armoria Real*

A typical horseman's axe features an anatomy of a front curved blade as well as either a pick or a hammer mounted on the back of the head. Some axes may even feature a top spike for further penetrating and a pommel based upon design requirements. A general idea of a horseman's axe common in the 1500s features these components as seen in Figure 1, and although not as pretty as the picture above, functional for means of war. The horseman's axe showcased above (Figure 1) is a sleek, clean weapon purposed for looks more than functionality. This may seem true for many axes found in museums today; however, many pieces of this time showcased engraved or etched designs. These etched or engraved designs alluded to royalty or higher-ranking positions within the military, and were not a quick and easy process to do. To achieve these patterns, the axemen would cover the face of their piece in wax, scratch out a specific design, and then dip the blade into an acid. For many knights, a decorative piece of weaponry or armor was a must; thus, the axe was no exception. This multi-faceted competition is unique in the fact that it focuses not only on creating a decorative replication but also a functional blade made to impose damage on whosoever it wills.

Copying the rich history and authenticity of a noble axeman in his behaviors of preparation and attention to detail, the "Southern Steel Company's" team from Georgia Southern has taken the time to create its very own horseman's axe. Careful planning and research were at the forefront of our process, and like a high-ranked military knight, we treated it as if we were going to battle with it ourselves. SFSA has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available. This report will further discuss the relentless efforts of our team through brainstorming, CAD iterations, Magmasoft simulations, mold creation, mold assembly, casting processes, post-processing, heat treatment, sharpening, and handling assembly, all completed to create the final product of our axe.

2. Design

2.1 Conceptualization

To begin brainstorming, we sat down as a team and watched all of the videos provided by the judges on design requirements, and took into consideration both the thought process of tackling this piece as well as striving for authenticity. Although excited to get personal artistic touches involved, we knew the integrity of the blade, as well as smooth processing, was our first priority. Through a research synopsis, we decided to model our axe off of the 16th-century German horseman's axe, the "Raven Peak" (*Rabenpick).* As seen in Figure 2, this axe specifically features the key characteristics of a horseman's axe, having both the half-moon shaped face as well as the back fork or pick. This axe specifically was ahead of its time as it incorporated the back spike early on for piercing protective breastplates, all the while showcasing artistry to its finest.

Figure 2. The "Raven Peak" German Horseman's Axe

A few prominent characteristics attracted us to this axe. To start, the wing-like flanges located on the back of the edge, toe, and heel were unique compared to those of others at this time. Attending Georgia Southern University, our school's mascot is an eagle, so we immediately decided we wanted to incorporate this into our design. We were equally satisfied with the pick profile and decided a wooden handle would be our most weight-efficient option. For the artistic envisionment, we planned on etching a wing-like pattern where an eagle head would be the connecting piece between our axe edge and the axe eye. Within the breast of our etched eagle, we decided to place the Germanic culture-inspired yew tree. Represented by the rune Eihwaz, this symbolic tree represents endurance and resilience. This resonated with us as we knew the path of creating an axe was not to be easy. We also envisioned the axe handle to be covered in runic symbols used by Germanic tribes through the use of a wood-burning tool to further tie our heritage to that of German descent. Once a rough idea was generated, we began to design our axe head using CAD, as seen in Figure 3.

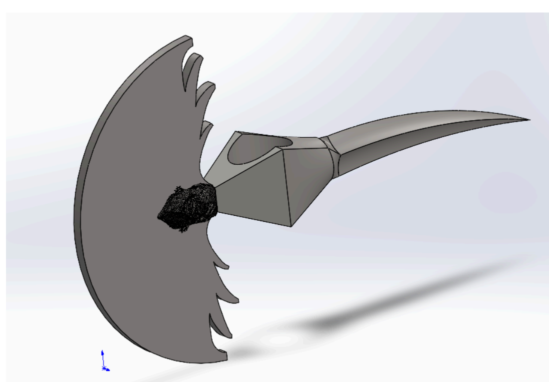

Figure 3. SolidWorks 3-D designed axe head drawing

2.2 Process Envisionment

In making our casting, we concluded that our axe head was of adequate proportion to be investment cast. Investment casting in this case was a no-brainer, as the intricate details we planned to include in our eagle face could be cast accurately. This would be done by creating a 3D printed part using a special PLA Polycast material. We would create an investment shell and then cast the head (Figure 3). We planned to cast the head with the edge, eye, and pick, having a hollow eye hole for us to wedge the axe into place. The pick itself was fullered and designed to be a bit longer than a standard-sized pick, as we liked the idea of being able to perform longer-range attacks. A pommel would be machined, and then a hammer threaded pin would be drilled and punched into the bottom of our handle, able to be screwed into place. For our handle, we decided to move forward with a pre-made wooden sledgehammer handle and would file it down to a proper fit aligned with our axe head. We would trim down as needed and then apply a leather wrapping for both style and comfort.

2.3 Alloy Selection

For the chemistry of the axe, 5 steels were considered for casting: 1045, 1095, proprietary 8630, 5160, and 9260. To determine the optimal material for the axe, a decision matrix was developed, evaluating materials based on tensile strength, ductility, hardness, and cost. Each category was normalized and summed together with the reciprocal of the cost added to the calculation, prioritizing a lower cost. The material with the highest final calculated score was then selected. Table 1 shows the decision matrix for material selection.

Table 1: Decision matrix for the material of the Horseman's Axe

	Tensile Strength (MPa)	**Hardness (HB)**	**Ductility (%)**	**Cost**	**Calculations**				**Final Score**
1045	650	195	8	29.76	0.00	0.00	0.00	0.83	**0.83**
1095	685	197	10	71.03	0.16	0.09	0.17	0.00	**0.42**
Proprietary (8630)	680	200	20	33.33	0.27	1.00	1.00	0.75	**3.03**
5160	724	197	17	21.08	0.34	0.09	0.75	1.00	**2.18**
9260	870	210	15	67.43	1.00	0.68	0.58	0.07	**2.34**

Due to the working conditions of this component, the selected alloy would need to possess great hardness, strength, toughness, and work hardenability. A proprietary steel that was custom-designed for ground-engaging tool applications was selected to meet the required mechanical properties of the axe. The target composition of the steel is 0.3C-1.1Mn-1.6Si-2.1Cr-051Ni-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. The actual composition and properties were tested in our university's labs and can be found in section 3.7.

3. Manufacturing

3.1 Gating Design and Simulation Methodology

After finishing our part design in SolidWorks, Magmasoft, a software tool to generate simulations of metalcasting processes, was used to help create our gating system. Three main factors are critical to consider in the successful filling of the mold: temperature, velocity, and air pressure. Temperature-wise, the metal must be at an adequate temperature to flow through the gating system and fill the casting without premature solidification. Using the technique of investment casting, our mold itself must be heated up alongside our molten metal. Maintaining uniform filling is equally important, as turbulent flow can splash molten metal and increase porosity. To avoid this, we considered the use of a smaller cross-sectional area in our runners as well as possibly implementing a choke within the gating system. Proper ventilation was also considered, as too much pressure within our investment shell could cause hot tears within our casting. Pressure, however, is very important in the filling procedure as a higher head pressure encourages quicker filling. Casting truly is an art, and we were tasked with painting.

With this information in consideration, we decided to move forward with a design where we oriented our axe heads parallel to our downsprue, as seen in Figure 4. Ensuring our axe head filled first, we placed our axe head with the edge in line with the bottom of our downsprue. We strategically designed our downsprue to act naturally as not only a pouring target but also a riser. This allowed the metal to creep into the ingates we attached to our axe eye. Our ingates were created to have a cylindrical shape where the metal was forced to climb a negative slope to enter the cavity. This slowed the flow of metal to combat the turbulent flow of metal, reducing porosity (Figure 4). We added vents into our Magmasoft simulation; however, we would be challenged with creating this outside of the 3D print itself. We then ran a simulation and initially changed our first design of casting 4 axe heads to doing just 2 axe heads for easier post-processing, as well as a lower amount of material used.

Figure 4. Magmasoft simulation representing the casting's porosity

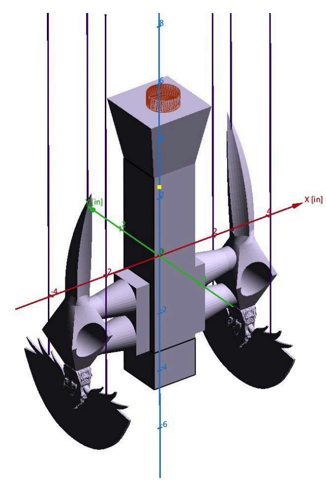

Figure 5. Magmasoft drawing iteration, including proper ventilation for simulating results

3.2 Mold Production

As briefly mentioned earlier, the pattern for the axe head was printed using a special low-ash PLA filament (Polycast) and smoothed out using a 70% isopropyl alcohol solution. Each print contained the downsprue pouring basin as well as a set of 4 axe heads, but was later changed to have just 2 axe heads. The molds were then dipped in a chronological procedure of slurry and stucco to create an investment shell. The first two layers of the stucco were fine zircon layers to ensure the shell encapsulated the details of our eagle face. Once the first two layers were dry, an additional six layers of coarse silica stucco were added to the shell to complete the process. Now it was time to burn out the Polycast PLA mold using a gas-powered torch apparatus. The investment shell was fired at 1562°F (850°C) for one hour to remove the pattern, as seen in Figure 7.

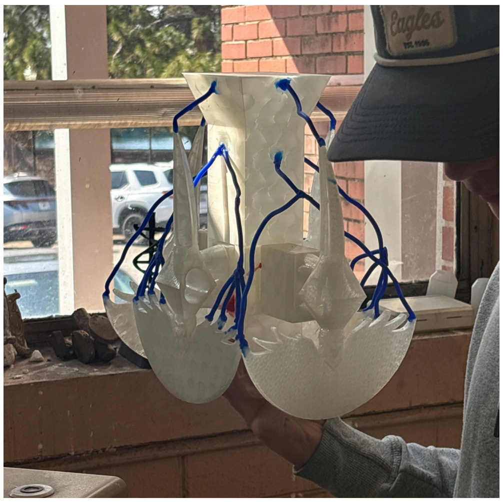

Figure 6. Assembled 3-D mold and attached vents, waiting to be poured

Figure 7. Burn-out and washed-out mold waiting to be pre-heated

3.3 Casting Procedure

To begin the casting procedure, we preheated our shell to roughly 1700°F (927°C) in a furnace oven. At the same time, our ladle was also pre-heated using a gas-powered torch. Our team safely walked through the casting procedures and triple checked that proper PPE was applied. Basic emergency plans were discussed, and a shovelman with sand was on hand. The castings were poured in Georgia Southern's foundry lab, where 8630 steel was melted in a 100-lb induction furnace under an argon-lanced atmosphere. Aluminum was added during tapping to kill the steel, and the molten steel was tapped at 3,100 °F and poured at an estimated 3000 °F. Castings were all broken out the next day to ensure full solidification and cooling.

3.4 Post-Processing

The cooled casting was separated from the mold by breaking the shell off the steel. Each axe head was cut off from the downsprue using an angle grinder to cut through the gating. Once the axe head was separated from the downsprue, the gating was ground off using an angle grinder, stone wheel, and flap disk. When the axe head was free from the gating, the stone wheel was used once again to remove the casting scale on the outside of the axe. A bevel was then created on the axe using a belt sander before being heat-treated, which is further discussed in Section 3.5. Once the heat treatment of the axe head was completed, the scales were ground off, and the axe head was polished using a rotary sander and polishing wheel. Multiple handle designs were tested, including two hickory handles and a fiberglass handle. The final design used was a hickory sledgehammer handle that was wood-burned and stained. The handle was cut to 18 inches in order to save weight, create a more effective weight distribution, and allow more dexterity. A half-inch wide, 2 millimeter thick vegetable tan leather strap that was paired with a 2 millimeter thick black leather cord to use for the handle. The vegetable-tanned leather was stained to achieve a darker, richer color. The pommel was cut using a lathe and threaded using a die at a size of ¼ 20.

To finish off some personal touches on our axe, an electrolytic etching procedure was done with a vinyl overlay placed on the cheek of our axe. We created this vinyl overlay using Cricut, placing the vinyl over the areas that we wanted to stay polished. To protect the eagle head, the edge, and the eye, we spray-painted over the surface, being careful not to spray over the unprotected blade, not covered by vinyl. We created a saltwater solution in a 5-gallon bucket and grabbed a battery along with positive and negative cables. The positive terminal was attached to the axe head and the negative to a sacrificial piece of steel. The axehead sat in the solution for 30 mins and then was pulled out. The vinyl was extracted, and the paint was cleaned off. Acetone and further gunmetal lubricant were added to improve the surface finish of our blade.

3.5 Heat Treatment Considerations

The head was first normalized by austenitization at 1700 °F for 1 hour, followed by air cooling. This normalization cycle was to homogenize the grain structure of the blade, relieve the internal stresses, and refine the grain sizes. A second round of normalization at 1700 °F for 1 hour was performed, followed by quenching in non-agitated oil to promote martensite formation. The axe head was then tempered at 400 °F for 1 hour. This is to precipitate fine carbides from the martensite, forming a tempered martensite microstructure in the blade, as shown in Figure 16.

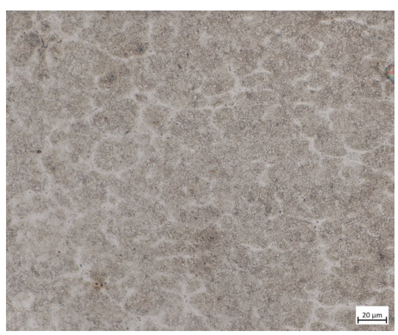

Figure 8. Microstructure of the Steel after all Heat Treatment with notable fine lath martensite

3.6 Final Result

All the components of the axe were brought together to fully complete the axe in both functionality and looks. The handle had various Nordic symbols burned into it using a woodburning pen before being stained. Once the stain was dried and wiped, the vegetable tan leather straps and leather cord were layered and attached to the handle using contact cement to ensure no movement of the leather upon use of the axe. A pattern was tied at the bottom of the handle and cemented to create an elevation of the bottom of the handle. A thicker, 1-inch-wide leather strap was then pinned at the top of the wrap in order to finish off the wrap and create a natural stop. A hammer-in, threaded insert was placed in the bottom of the wood where the 304 stainless steel pommel was screwed in and epoxied to ensure that it was secure. The axe head was then placed onto the handle and hammered on from the top using a standard claw hammer and a dead blow hammer from the bottom of the handle. A wooden wedge and epoxy were then used to secure the head onto the wood. A steel wedge was then used perpendicular to the wedge. The excess epoxy was sanded away, and the axe was cleaned up. The axe weight totaled up to be 2.94 pounds and had a length of 21 inches. The axe blade had a total length of 7.3 inches, and the spike had a total length of 5.2 inches. The measured length of the tip of our spike to the outermost part of our blade was 11.7 inches.

3.7 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 2. The chemistry meets the specifications for our modified 8630 steel.

Table 2. Composition (wt. %) of the steel

	C	Si	Mn	Cr	Ni	Mo	Al
wt. %	0.35	1.60	1.01	1.99	0.49	0.325	0.0103

For the actual testing of the axe, several destructive tests were performed to determine the chopping and kinetic force emitted from the axe. Concerning NDT, we took into account the chemistry and mechanical properties tied to our material selection. To properly explore the limits of our axe, we went for a destructive testing approach instead. Testing included a steel drum, blocks of ice, fruit, and a wooden 2x4. In our first design, we broke our axe head, failing where the eagle head meets the wings. This proved to be a major stress concentration and a flaw in our design, as the angle between the two was quite drastic. Smoothing out the angle, we were able to adequately create another iteration of our axe head, and were pleased to say our blade held up to testing.

4. Executive Summary

Our axe was designed with the intent of replicating the 16th-century German cavalry battle axe known as the “Raven Peak”. The design replicates the major components of the axe while also adding a bit of Georgia Southern’s flair, showcasing our beloved eagle mascot. Our alloy was selected among a variety of steels based on their mechanical properties and cost-effectiveness.

The gating system for the blade went through several simulations to ensure the optimal pattern had been developed and a high-quality casting would be produced. The axe head was cast in an investment cast shell to meet the final horseman axe requirements, weighing 2.94lbs. Our axe head length was 11.7 inches, and the length of our axe was 21 inches.

After post-processing, the blade was heat-treated through a normalization cycle for 1 hour, and air-cooled, followed by a quenching cycle for another hour. This was then followed by a quench in non-agitated oil. Finally, the axe head was tempered for 1 hour to give our axe head a microstructure of fine lath martensite. After heat treatment, the axe head went through a series of grinding and polishing as well as an etching procedure.

Many difficulties were encountered during this project, ranging from design issues to machining and post-processing issues. Through it all, we were able to create a satisfactory replication of the “Raven Peak” horseman’s axe. Our team would like to thank our industry partner, Carolina Metal Castings, as well as our faculty advisor, Dr. Mingzhi Xu, for guiding us through our troubles and mistakes and being patient while we produce such a fantastic piece of history.

5. References

"Catalogue." *Denix*, www.denix.es/en/catalogue/medieval-europe-vi-xv-c/battle-axes-halberds/6602/. Accessed 27 Mar. 2026.

Ellis, Russ. "Horseman's Axe." *myArmoury.Com*, myarmoury.com/review_aa_haxe.html. Accessed 27 Mar. 2026.

"Halberd of Prince Karl I of Liechtenstein (1569–1627)." *German - The Metropolitan Museum of Art*, www.metmuseum.org/art/collection/search/22965. Accessed 27 Mar. 2026.

"Yew – Tree of Death and Longevity " Imperium Romanum." *Imperium Romanum*, 20 Nov. 2025, imperiumromanum.pl/en/curiosities/yew-tree-of-death-and-longevity/.

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