

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

Arizona State University – the Heatwaves



Team Members:

Skylar Schineller

Cassie Klenk

Tamara Ramirez-Saumell

Advisor Name:

Chris Luper

Foundry Partner:

ME Elecmetal

INTRODUCTION

The following technical report describes the design, fabrication, and subsequent processes of a historically inspired Horseman's axe. The Steel Founders' Society of America (SFSA) has created this competition to encourage students to learn about making steel products through the casting process and to apply the latest available technology. Cast in Steel 2026 challenges university student teams to design and produce a functional Horseman's axe using steel casting, integrating historical research, modern engineering design tools, and professional inspection standards, helping students gain hands-on experience with both modern industry and older metalworking practices.

HISTORICAL BACKGROUND AND AUTHENTICITY

The horseman's axe emerged as a cavalry sidearm during the medieval period. At the time, it would not have been cast in steel; it would have been forged by a blacksmith, likely using a type of iron with higher impurities than modern metals.

According to an email from Professor DeVries at Loyola University, Honorary Historical Consultant and expert in armor and medieval military, "The horseman's axe was one of several hand-held weapons that cavalry, especially knights, would use in battle, especially in the later Middle Ages. Swords needed more training to be used effectively in battle. And they were difficult to use in melees with other horsemen as there was space between combatants to use a sword effectively... Axes produce sharp-edged wounds, which would kill more often than blunt-edged weapons. A hammer produced blunt-edged weapons or, turned around, puncture wounds with the point on the rear of the weapon." (DeVries) He did mention that our design was likely more ornate than was used in battle, as horsemen's axes were made for forceful blows rather than for show.

By the 12th century, a variety of single-handed battle-axes had been adopted by the noble class of Europe as horsemen's weapons. By the 15th century, horsemen's axes had a revival among heavily armored equestrian combatants. King John II is recorded as using one at the Battle of Poitiers in 1356, and Robert the Bruce, King of Scotland, famously used an axe to defeat Henry de Bohun in single combat at the start of the Battle of Bannockburn in 1314. (Oakeshott) Given that Bruce was wielding the axe on horseback, it is likely that it was a one-handed horseman's axe.

The horseman's axe was built for mounted combat. The convex edge and swept concave head of the broadaxe could be used to best advantage by performing a 'draw cut' on horseback, an arcing overhead stroke that used the forward momentum of the horse to deliver devastating blows. The haft was designed to be wielded in one hand, allowing the rider to retain the weapon during combat and carry it at the saddle.

Our axe is modeled on documented European horsemen's axes from the last quarter of the 15th century, consistent with the example cited in the SFSA competition brief [Fig 2,], which dates to approximately 1475 and measures 69 cm (27 inches) in length. Additional reference was made to the Horseman's Axe of Cardinal Ippolito de' Medici (ca. 1511–35) [Fig. 1], held at the Metropolitan Museum of Art, which measures 78.1 cm overall, with an axe head measuring 5.25 inches.



Fig. 1: Horseman's Axe of Cardinal Ippolito de' Medici *Fig. 2: Horseman's Ax Circa. 1475*

DESIGN PROCESS

Historical Research and Concept Development

The design process began with a review of primary and secondary historical sources, including records from the Metropolitan Museum of Art, references to medieval cavalry weapons, and the depiction of a battle axe on the Cast in Steel Website. The team identified the key functional and

aesthetic features of authentic 15th-century horseman's axes and developed a set of design requirements:

- Overall length: ≤ 800 mm (31.5 in)
- Weight: ≤ 1.5 kg (3.3 lbs)
- **Crescent-shaped blade:** Convex cutting edge optimized for strikes from horseback,
- **Top pick spike:** Made for penetrating armor joints and stabbing.
- **Parallel spike:** Ornamental / Counter-balance to blade.

The original sketch was freehand on paper [Fig. 3], and the design for the axe-head was formed in clay [Fig. 4] in preparation for sand molding.

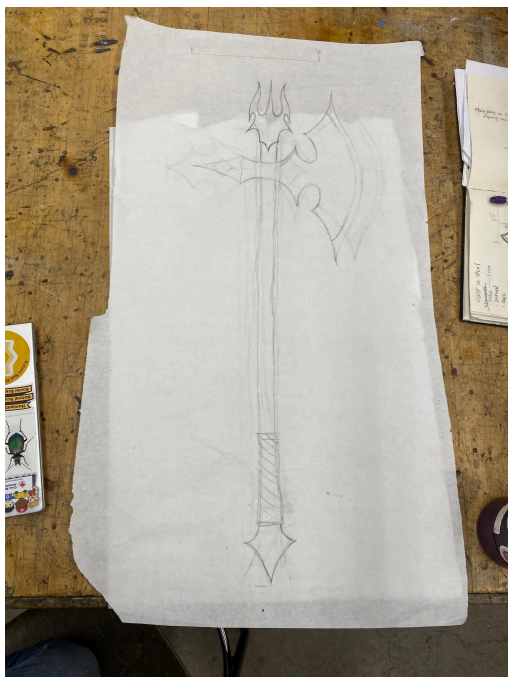


Fig. 3: Freehand draft sketch



Fig. 4: Clay sculpture of draft sketch

METALLURGICAL DECISIONS

4130 Chromoly steel is a low-alloy steel named for its chromium and molybdenum content. As a result, it is also known as chromium-molybdenum steel. It is also known as alloy steel grade 4130, where the "30" is approximately 0.30% carbon by weight. Chromoly steel was selected as the alloy for the axe head, based on strength and durability after heat treatment, per our foundry partner's recommendations. The chromium in the alloy adds Non-Chromoly steel or mild steel, which is a mix of iron and carbon, which is weaker in strength; more mild steel has the same strength as less chromoly (Quinn-Walsh). Chromoly steel is used more often when steel is seen for performance.

CASTING PROCESS

Sand mold: Following the clay sculpting process, a sand mold was made by surrounding the clay sculpture with sand in a wooden mold, held in place with clamps [Fig. 5].

Fig. 5: Sand mold of Ax



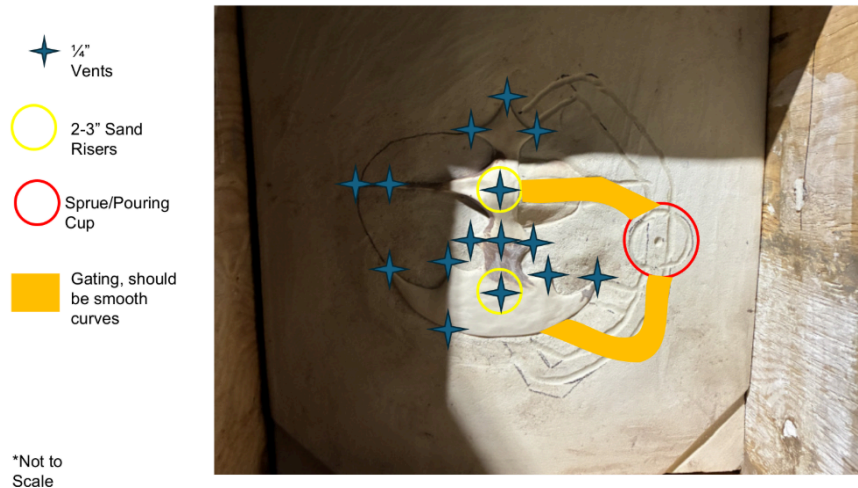
Fig 6: Gating system



Gating:

Original gating system after sand mold, [Fig. 6]. Chase at ME Elecmetal recommended alterations to our gating system, including adding risers to feed additional metal into the mold as it shrinks and cools to prevent voids. The risers were recommended to be around 2-3 inches in diameter in the marked locations [Fig. 7]. We were advised to add ¼-inch vents at the marked locations to allow air to escape. The team drilled both alterations into the cope for controlled solidification.

Fig 7: Refined gating system



Steel pour: We sent the gating with the additional alterations to ME Elecmetal for steel pour and casting [Fig 8]. After casting, they removed the steel from the mold and ground the risers and remaining gating off [Fig 9].



Fig. 9: Gating and riser removal (Left)



Fig. 8: Steel pour and casting (Right)

HEAT TREATMENT:

Following casting and initial grinding, the axe head was heat-treated to achieve the hardness and toughness required for competition performance.

The heat treatment sequence was as follows:

1. 1850F, 1 hour at heat, then cool in stagnant air:

This is a normalizing treatment, standard fare for steel castings, and is done by heating the steel about 50 - 100F above the quenching austenite temperature, then cooling in still air. Since the crystal grains present may lack homogeneity (in size and shape) after solidification, the normalized treatment is used to create a fine pearlitic structure that is uniform and free from microstructural defects. When determining soak time, thickness must be considered, and is typically defined as the minimum dimension of the heaviest section of the part. As the casting solidifies, sections of varying thickness will experience different cooling rates (during which the melted alloy will shrink significantly), thus normalizing also relieves the thermal stresses induced by said solidification. The slow cooling is imperative for the formation of ductile pearlite (as opposed to hard martensite).

2. 1800F, 1 hour at heat, agitated air quench:

This is the austenitizing and quench treatment, which will transform austenite to martensite. The critical austenite temperatures ($Ac_{1,2,3}$) as well as the somewhat higher temperature you should quench your steel from, are determined by both the alloying and carbon content present; for instance, chromium will raise it, and nickel will lower it. Carbon content will also lower it until the eutectoid composition (0.76 - 0.83%) is reached, after which it will increase with increasing carbon percentage (see the Fe-C phase diagram, Fig. 10). The presence of carbon and alloying (especially manganese) will also lower the cooling rate required for martensitic transformation. Quench oil was not readily available, so we elected to cool via agitated air instead.

Iron-Carbon Phase Diagram

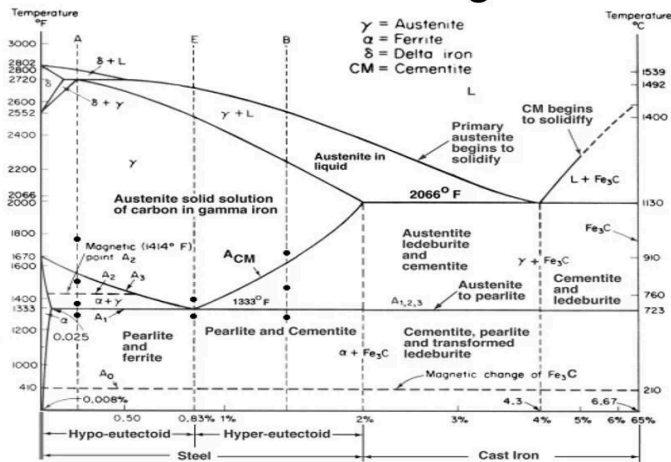


Figure 10: Fe-C Phase Diagram (Ferguson, Lynn & Li, Zhichao & Sims, Justin & Yu, Tianyu. (2017))

3. 500F, 2 hours at heat, then cool in stagnant air:
This is the initial tempering cycle. It serves not only as a thermal stress-relief but also to transform any untempered martensite, a metastable phase present post-quenching. This must be done within a certain window of time

(recommendations from ME Elecmetal were 2-4 hours maximum), otherwise the untempered martensite will transform into other phases, and you will have to austenitize and quench once again. During this thermal process, the carbon atoms used to form martensite during quenching migrate and form eta-carbides, reducing material strength but greatly increasing toughness. Before the next step, however, the steel must cool to ambient temperature to ensure the effectiveness of any subsequent temper(s).

4. 500F, 2 hours at heat, then cool in stagnant air:

This is the second and final tempering cycle. [Fig. 11 and 12] It is generally not required for most alloy steels unless they are carburizing grade or nominally high in carbon. The goals of this operation are to temper any remaining untempered martensite and to transform remaining retained austenite into martensite. Austenite is the crystal phase to which ferrite fully transforms after the critical temperature Ac₃ is reached; additionally, the higher the carbon concentration, the more likely austenite will be retained after quenching. Some retained austenite will be eliminated with just a single temper, but alas, it is common practice to perform a cryogenic treatment (typically -90 to -120F) between tempers to remove the retained phase. Since austenite is a soft phase, it is generally not desirable in blade and tool applications.



Figure 11 (left) and Figure 12 (right): Second tempering cycle

After heat treatment, we ground out larger imperfections in the casting with an angle grinder; there were no visible structural issues. Pre [Fig. 13] and post [Fig. 14] further buffing and refining, the team sharpened the axe blade at this stage.



Figure 13: Axe head after initial grinding (left)

Figure 14: Axe head after further refinement (right)

THE HANDLE

Using an Ash block, chosen for its strength and flexibility, our team cut it down to 28 inches to accommodate a 4-inch blade height. The blade will have around an inch of insert into the blade head itself, aiming to create a handle 25-27 inches long, which accommodates our length restrictions. We sketched a design with flared-out spikes spaced 4-6 inches apart to accommodate one-handed holding [Fig. 15]. The handle was roughly shaped at this step with an angle grinder and a belt sander [Fig. 16].



Fig. 15: Concept sketch for handle

Fig. 16: Handle rough cut

Further refinement consisted of thinning out the handle with sanding discs. We opted to apply a burnt finish to the wood for aesthetic purposes. We then applied sealant to preserve the markings. For attachment to the axe head, a wedge system was used to thin the top of the handle by feathering with a wood chisel, using trial and error for a snug fit (Fig. 17). Langets were added to reinforce the head to shaft connection. As for shipping, we opted for a box made of several 2 x 4 planks, roughly cut at 6 inches, to serve as a frame for an MDF box (Fig. 18).



Fig 17: Finished haft

Fig 18: Building materials for shipping box

NON-DESTRUCTIVE TESTING (NDT)

Visual inspection was the first and primary method used on the casting. The casting was examined under bright light and magnification for surface abnormalities, including cracks and porosity. This was performed at three stages: immediately after removal from the casting, after initial grinding, and after heat treatment.

Visual Inspection	Pass. No cracks and/or weak spots after steel casting and heat treatment. Slight porosity consistent with the steel type.
Hardness	Pass. Hardness value is consistent with typical castings.
Chemical Composition	Majority steel, trace amounts of potassium, sodium, tungsten, and chromium.

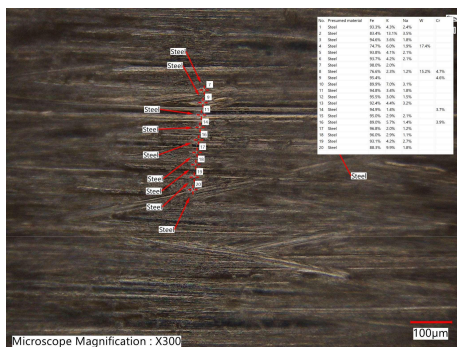


Fig. 19: Chemical Composition Analysis

FINAL RESULTS

Overall Length	30.5 in.
Weight	2.5 lbs.

CONCLUSION

We extend our sincerest gratitude to Carlos, Damon, Chase, and Alex for their assistance with our Cast in Steel submission. Our team successfully designed and produced a functional, historically authentic Horseman's axe for the SFSA Cast in Steel 2026 competition. The axe is modeled on documented 15th-century European cavalry axes, incorporates all period-authentic functional features, and was produced using steel casting to replicate the original geometry. The casting was subjected to a comprehensive overview with inspection and meets all competition dimensional and weight requirements.

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