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

Purdue University – The Five Horsemen

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Foundry Partner:

Waupaca Foundry (Plant 5)

1.0 Introduction

Why Cast in Steel

Steel Founders' Society of America, also known as SFSA, has created the Cast in Steel Competition to encourage students to learn more about making steel products using the casting process and applying the latest technology available. This allows for wider involvement of new casting technologies and techniques for students involved in the industry, as well as inter-university friendly competition.

Historical Background/Accuracy

An axe is classified as either a tool or a weapon consisting of a sharp blade attached to a handle used to cut, chop, or cleave through objects. Axes have been utilized since 6000 B.C and initially consisted of a stone blade attached to a wooden shaft. By the iron age in 1000 B.C., the stone head was replaced with an iron head, and the wedge-shaped iron axe became the standard form. [1] Battle axes were often cheaper to manufacture compared to swords since only the head needed to be forged while the handle could be constructed out of a cheaper material such as wood. Even though swords were favored by knights, axes began to gain traction by the turn of the 12th century, with various European nobles utilizing one-handed axes in combat. Most notably, King Richard the Lionheart supposedly utilized a two-handed battle axe to great effect during crusades in the Middle East. [2] While there are a plethora of different axe designs, the horseman's axe was utilized by mounted knights during the mid-14th century all the way to the late 18th century. Since this axe variant needed to be used by mounted warriors, the horseman's axe feathered a longer, stronger handle along with a top spike for stabbing. This weapon was mostly effective against lightly armored opponents or mailed footmen.

Figure 1 depicts Richard the Lionheart with his battle axe in 1190.

2.0 Modeling/material decisions

While researching various one-handed horsemen axes, we were looking for three key characteristics: aesthetics, performance, and historical authenticity. All five group members came up with various designs for horsemen axes, and a vote was cast to determine which design looked the best and was the most feasible. The final design utilized a spike like Purdue's iconic bell tower, along with a short hammer with the letter P engraved in it, representing Purdue university. On the rear end of the blade, additional curl extensions were added, which were heavily inspired by German designs. The final handle design is oval shaped to allow ease of handling and leather embroidered grip. These design considerations were pulled from photos of existing axes from the 14^{th}-15^{th} century, and the various features were discussed and considered for our model from historical literature on the use and motivation for the inclusion of the features, as well as what we as a group are physically capable of, utilizing foundry partnership and university assistance. The Purdue P could not be engraved into the hammer with the methods available to our team and would have been too fine of a detail to cast in sand along with the cavity that would have been left with the mold pressing.

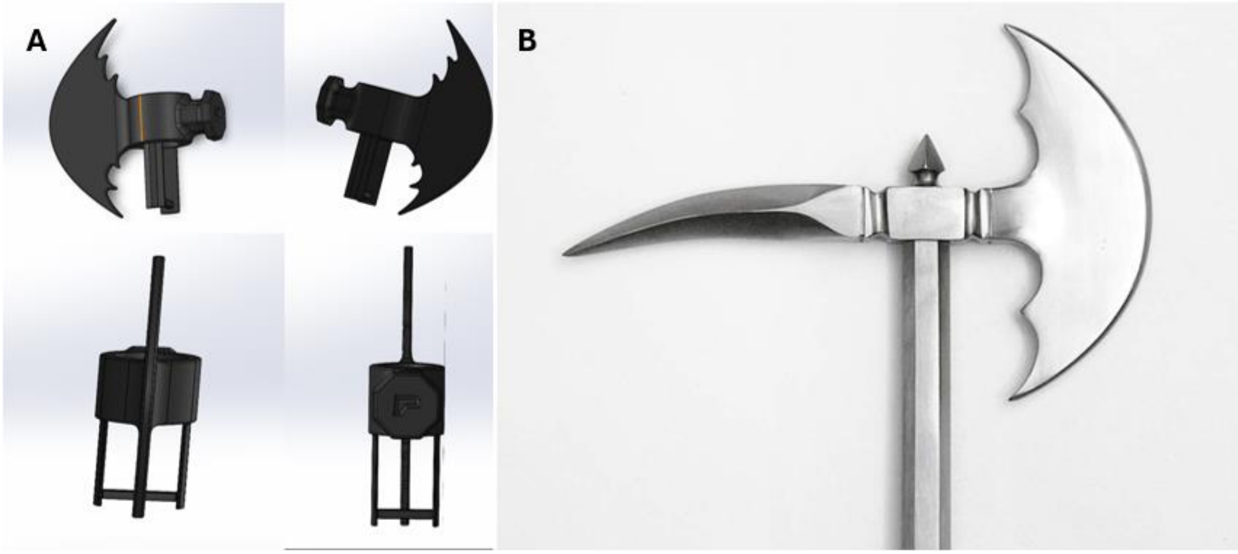

Figure 2 shows a 15th century Germanic horseman (right) axe that inspired the subsequent design iterations (left)

Casting Method

A quick drafting method for a porotype mold was made using a printed running and gating system put together by the joint effort of Waupaca advisory and the gating designs of the team. The sand cast utilized the continuous vertical molding lines of Waupaca foundry to integrate the mold into the pouring line seamlessly alongside normal ductile iron production castings. A sand core was used to allow a cast bore that would not need to be drilled in the future. The blank axe was easily ground to a conical profile to withstand any rolling of the edge.

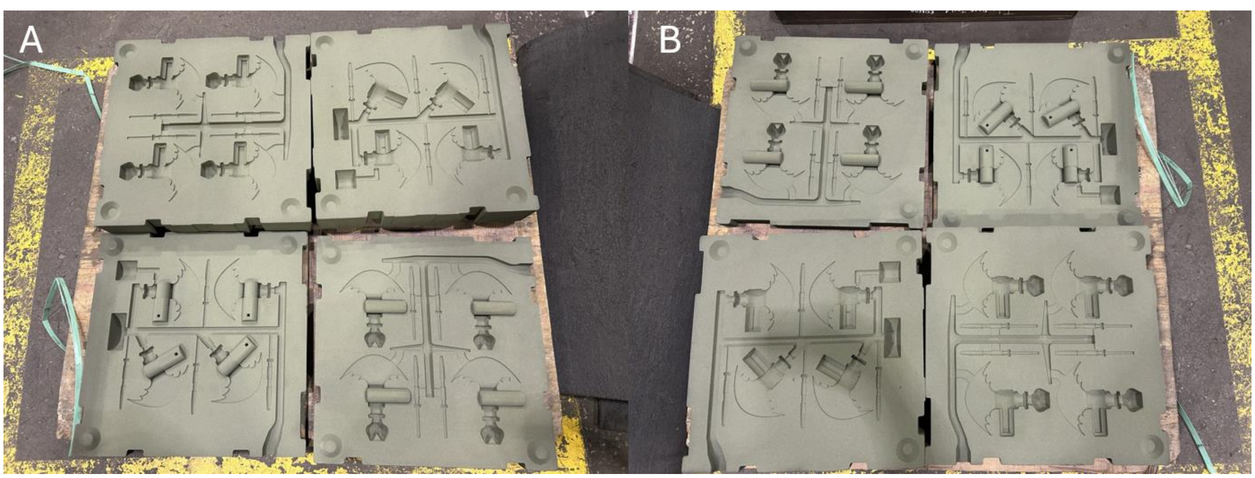

Figure 3 shows the sand molds pressed in Waupaca Foundry used for the final castings

Metallographic Decisions

Normally, bladed weapons such as swords and axes are constructed using a steel alloy such as 1095 steel since it is imperative that the blade has a high toughness and hardness to withstand impacts while also being ductile enough so that it won't crack under those same forces. As a result, metals such as 1095 steel are preferred for blade construction since it already has a high hardness (65-67 HRC) and can be heat-treated to further improve its ductility. [4] Unfortunately, Waupaca foundry specializes in ductile iron or grey iron and does not have the capabilities of casting steel. This initially posed a significant problem for our team since grey iron has a carbon content of 1.5% to 4.3%, meaning that it is extremely brittle while also having a low tensile strength. The main strength of grey iron is the fact that it has excellent vibration damping capabilities and high compressive strength, which are not essential for blade making. [5] Since grey iron is an unacceptable substitute for steel, that left us with only ductile iron as a viable option. By itself, ductile iron is twice as strong compared to grey iron and has considerable elasticity, impact resistance, and yield strength. [6] However, once thermally processed, ductile iron acquires mechanical properties comparable to 1095 steel. Initially, austempering was considered to produce a bainitic microstructure to balance hardness and toughness that would support the strength of the ductile iron microstructure, but the salt bath quench was not within the capabilities of our team, so a heat treat cycle for martensitic microstructure formation was performed instead, sacrificing some toughness for a harder final product. The final measured hardness of the blade came out to 65 HRC among three readings.

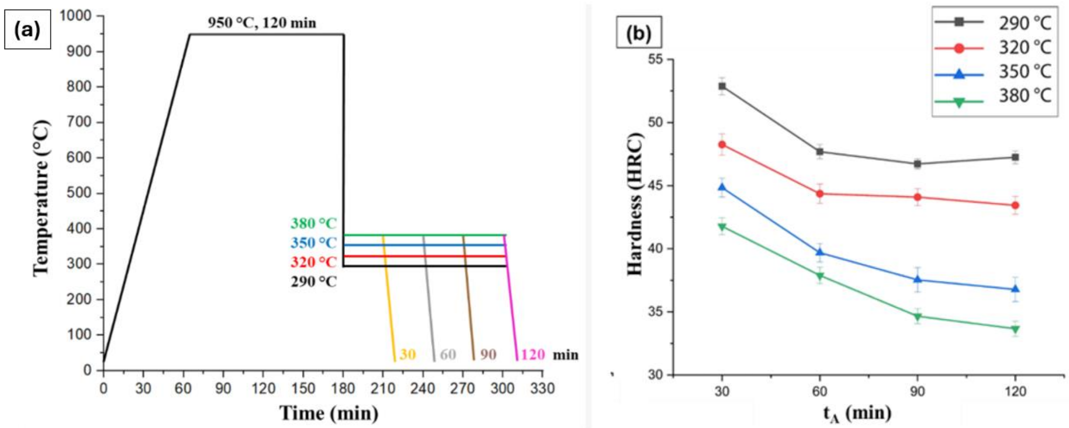

Figure 4 shows the heat treatment cycle for ductile iron (right) and the expected hardness from the temper cycle (left).

Destructive/Non-Destructive Testing

Once the axe head was austempered and subsequently sand blasted, we utilized a Rockwell hardness test to determine the HRC of our blade. Just like our temper cycle predicted, we got a hardness of 48 HRC around three various points on the edge of our blade. This is an exceptional result since this means that the blade is hard enough to maintain its shape during testing while being ductile enough to not shatter upon impact. Besides conducting a Rockwell hardness test after the heat treatment process, we also took a sample of ductile iron before and after the thermal treatment. With these samples, we attempted to polish and etch the samples, but due to safety concerns, we were unable to acquire nitol for the etch. As can be seen in figure 5, even without the etch, ductile iron's distinctive spheroidal shaped graphite's can be observed. If we were able to etch, then ductile iron's pearlitic matrix could be observed, which heavily contributes to the metal's ductility.

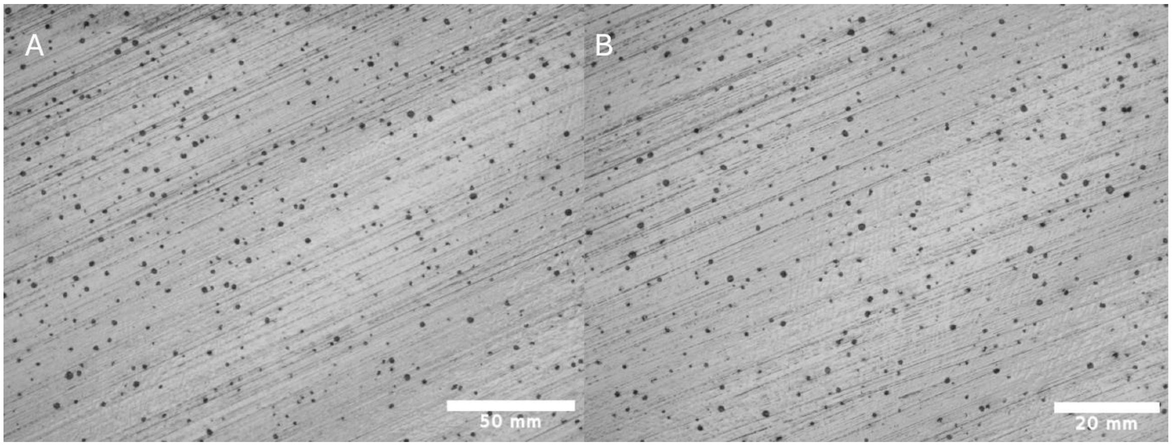

Figure 5 shows the microstructure of ductile iron before the heat treatment.

Besides utilizing a hardness test to determine the integrity of our blade, we also made visual inspections of the axe head to see if we could determine any defects that may have occurred during the heat treatment process. With this visual inspection, a plethora of pitting could be observed near the blade of the axe and on the main chassis of the weapon. Since the pitting seemed limited to only the surface of the axe, we decided to blacken the surface using phosphate.

Results

The final axe came out to 21 inches and a final weight of 38oz within the requirements of the maximum length and width of 31.5 inches and 3.3 lbs. The axe blade was also constructed using ductile iron while the handle is made from American hickory.

Bibliography

[1] Warfare History Network. "The Battle-AX." *Warfare History Network*, 29 Jan. 2026, warfarehistorynetwork.com/article/the-battle-ax/.

[2] Stronghold Nation. "Horseman's Axe." *Stronghold Nation*, 2013, www.stronghold-nation.com/history/ref/horsemans-axe.

[3] Rodríguez-Rosales, Nelly Abigaíl, et al. "Statistical Data-Driven Model for Hardness Prediction in Austempered Ductile Irons." *MDPI*, Multidisciplinary Digital Publishing Institute, 15 Apr. 2022, www.mdpi.com/2075-4701/12/4/676.

[4] Xia, Gavin. "Ein Vollständiger Technischer Leitfaden Für 1095 Stahl: Zusammensetzung, Eigenschaften, Wärmebehandlung Und Industrielle Anwendungen." *Rapid*, 18 Nov. 2025, www.rapid-protos.com/de/1095-steel-guide/.

[5] "Grey Cast Iron - an Overview | Sciencedirect Topics." *Gray Iron*, ScienceDirect, 2010, www.sciencedirect.com/topics/engineering/grey-cast-iron.

[6] TB Woods. "TB Wood's Ductile Iron." *Ductile Iron Redefined*, Regal Rexnord Brand, 2026, www.tbwoods.com/commercial-castings/ductile-iron.