

# SFSA Cast in Steel 2026

## Horseman's Axe Technical Report

Ferris State University – Bulldog Casting Crew



FERRIS STATE  
UNIVERSITY



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## Introduction

SFSA has created Cast in Steel to encourage students to learn about making steel products using the cast process and applying the latest technology available. When participating in the Cast in Steel event it allows students an opportunity to get hands on experience and learn more about steel foundries and the advantages of the casting process. Our team, The Bulldog Casting Crew is a 1<sup>st</sup> time competitor in the Cast in Steel competition and is comprised of 3 juniors studying welding engineering.

Our thought process started to research the history of the horseman's axe. By looking at the historical background, we got an idea of how the axe was used throughout history by mounted warriors. Our goal was to make the axe historically accurate in terms of shape and material, based on the examples we researched online.

We developed our design in CAD and from there we were able to use MAGMASOFT® software to help simulate the pour. Our axe was then processed and heat treated. NDT was our next step to catch any discontinuities prior to finishing the axe heads. After NDT our team began finishing the axe head was next, after a few unforeseen issues we were able to complete the axe heads final shape by grinding it. At the same time our handle was made. The last step was for the team to quench and temper the axe and add the final cutting edge on the blade.

The process of designing, building and finishing the axe really gave us a front row seat to the entire casting process. From touring the foundry for the first time to seeing what it is a foundry does, to working with Eagle Alloy, Inc. to select the material, and what and why the risers and gating are where they are and what they do is really eye opening. Being able to be a part of the Cast in Steel process has opened many doors into the casting world.

## Historical Background

From our research we found that a horseman's axe is a historical weapon used by mounted warriors during the medieval period. It was a compact, one-handed weapon designed for use on horseback, lightweight enough to allow the rider to strike effectively while maintaining control of the horse. As armor and weapons evolved, the horseman's axe was developed to penetrate plate armor, often featuring both a blade and a spike.

These practical features of simplicity, affordability, and effectiveness made the weapon popular for many years and are what make our horseman's axe historically accurate. Our replica follows the authentic design with a one-handed, compact, balanced, and lightweight construction. It also features a dual-purpose head with both a blade and a spike, reflecting the original design intended to penetrate armor opponents. The only slight difference between our replica and the historical accurate model we chose to emulate was that we chose to use a wooden handle due to the weight restrictions. All other major characteristics of an authentic horseman's axe are preserved in our historical replica.



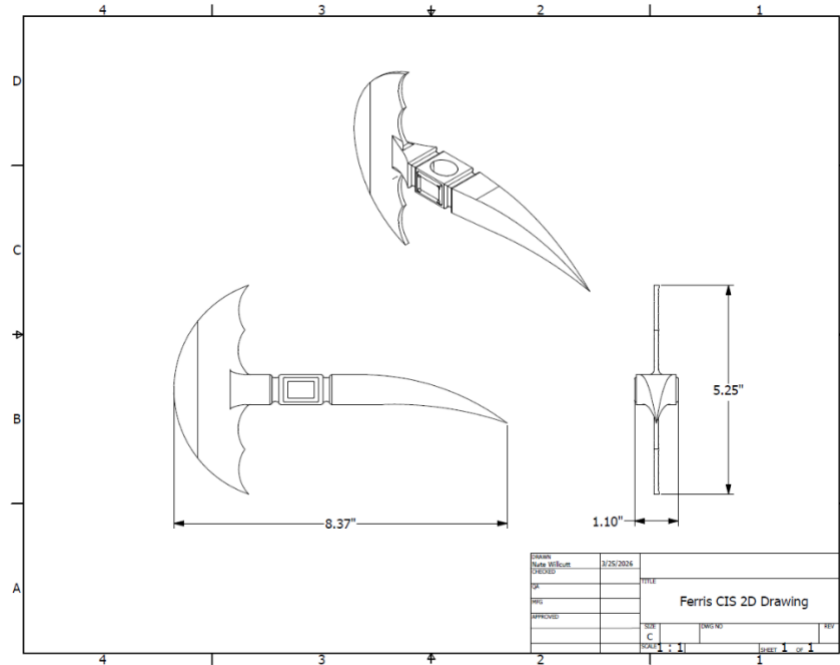
## Use of Casting Technology

When considering the casting process a few things are considered. Number of parts, production rates, part shape and surface finish are all important factors. Our group had two options for casting – a 3D printed sand-casting mold or an airset casting mold. The 3D mold offered a high quality, as cast surface, and more complex geometries can be implemented allowing more flexibility because you are not limited to draft created by tooling so the mold can be pulled from it. However, due to the number of axes being produced the cost was not justifiable and 3D printed molds are limited to a single use so if we had any scrap we would have been put in a tight spot for time if more needed to be reprinted. By going with the airset mold, we were able to reduce the cost and we were able to control the design and production of the tooling. Which gave us the freedom of being able to produce as many axed heads as we needed with the option to make more in a timely manner if parts did end up becoming scrap during pouring and/or post processing.

## Design Process and Post Processing

The design process for the axe began by researching historical images of authentic horseman's axes to develop a design that maintained the traditional appearance while still meeting the project requirements. Using the given weight and size constraints, our group decided to use a wooden handle instead of a cast handle, which helped keep the total weight of the axe below the maximum allowed limit while still maintaining strength and usability. We also considered other avenues, like casting an axe head around a titanium tube. But we would have not been able to use the 5 axis CNC machine and we couldn't say for certain we were going to meet the weight requirement if we went that route.

After the initial design concept was finalized, we worked with our industry partner to generate a detailed CAD model of the axe head. We then sent the model to our sponsor where they applied the draft and then determined the best gating methods. This includes the in-gate location, risers, and the number of impressions for tooling and corebox. The tooling was then optimized in MAGMASOFT®.



The gating assembly and feeding system were designed using MAGMASOFT® simulation software, which allowed the proper placement of risers to reduce shrinkage defects and ensure proper metal flow during pouring.



The generated gating assembly pattern was then 3D printed and attached to our sand boxes so the mold cavities could be formed by packing sand into the pattern.



Once the sand was packed, the molds were opened and cleaned, the core was installed, and the cope and drag were glued together to prepare the mold for pouring.



A small piece of paper towel was placed on the sprue opening to prevent dust or debris from entering the mold during transportation to the pouring station. At the pouring station, 8630 steel with additional carbon added for increased hardenability was poured into each mold and allowed to solidify.



After cooling, the castings were removed from the molds. Due to the two gating assembly patterns being approximately 0.050 inches out of tolerance from the 3D printing process, excessive parting line runout was present and required extra post-processing. The risers were removed using an oxy-fuel torch, and additional grinding was performed to clean the casting.

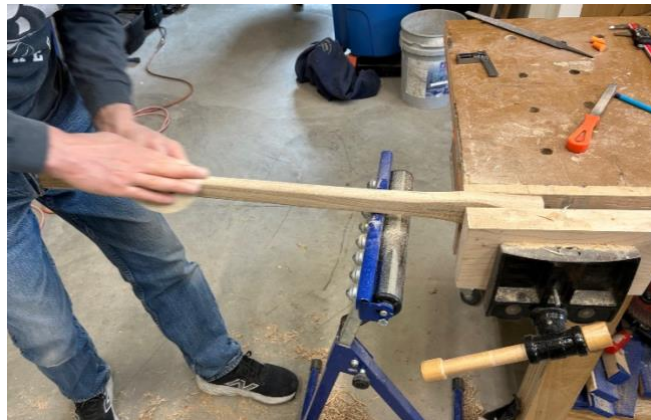


The axe heads were then normalized in a furnace to create a more uniform grain structure throughout the material. After heat treatment, excess draft material was removed using an angle grinder with a grinding disc, followed by shaping with a flap disc to prepare the blade. The original plan was to machine the axe head using a 5-axis CNC machine, but due to the machine being out of service, the remaining material removal had to be done manually. The team used handheld grinders to take the as cast axe head (left) to the finished axe head (right). Another problem we ran into was the core. When casting the axe the cores shifted/ twisted inside the mold this caused the location of our hole to favor one side. Our first thought was they would need to be recast, which was an option due to picking the air set molds. But we decided we would adapt and widen the hole.



The blade and spike were then hardened using an oxy-acetylene torch, heating the areas to the austenitizing temperature, followed by quenching in 100°F water, and then tempering at 350°F for 45 minutes to achieve a tougher material.

The handle was made from white oak to provide strength and durability. Starting with a 2 in × 1 in × 30 in block, the material was first squared and flattened using a jointer, then the rough shape was cut on a bandsaw. Final shaping was completed using a spokeshave until the handle reached its final form.



The handle was then attached to the axe head using a steel wedge to ensure a secure fit. Through these steps, the final product was completed while meeting the required design constraints, maintaining structural integrity, and following proper casting, heat treatment, and finishing procedures.



## Inspection and Non-Destructive Testing

To ensure the integrity of our axe, non-destructive testing methods were used with the help of our industry partner. The axe heads were inspected using both magnetic particle inspection (MPI) and radiographic testing (RT). These methods allowed us to evaluate the quality of the casting without plastically deforming the part.

Magnetic particle inspection was used to detect surface discontinuities that are common with casted components. During this process, the axe head was magnetized, and magnetic particles were applied to the surface. The particles gather in the areas where the discontinuities are, enhancing the visibility of the defects. This allowed us to check for common casting defects like surface cracks and porosity.



In addition to MPI, the axes were also inspected using radiographic testing to evaluate the internal discontinuities. The axe heads were exposed to X-rays, and the image was recorded on film, which was then viewed on a light screen to identify any internal defects. Discontinuities appeared on the film as darker areas compared to the rest of the axe head due to increased radiation exposure in those locations. These darker indications occur because there is less material in those areas, allowing more X-rays to pass through and expose the film. This testing allowed us to evaluate the casting for internal defects such as shrinkage porosity, internal voids, inclusions, and tin-can type discontinuities. These types of discontinuities can be found in cast components and, if severe, can significantly reduce the overall integrity and strength of the part.

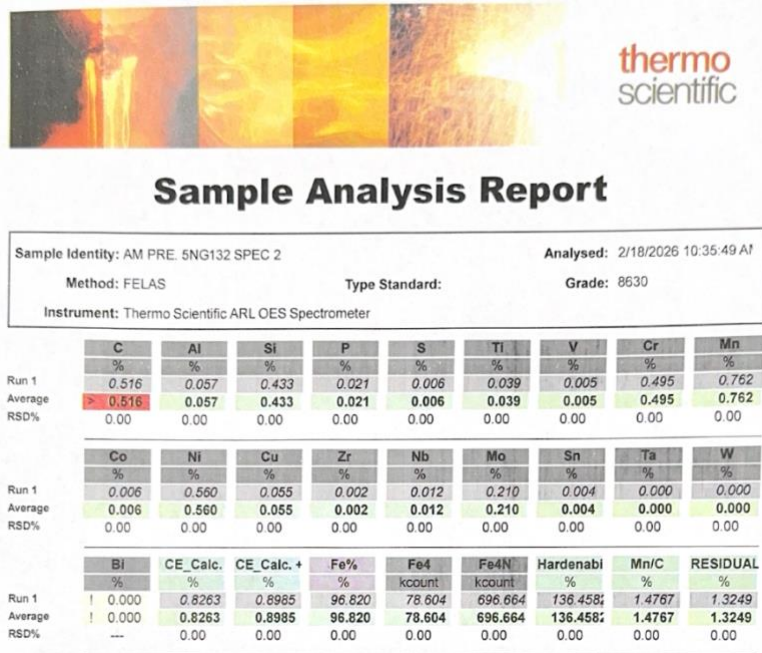


By using both magnetic particle inspection and radiographic testing, we verified that the axe did not contain any critical surface or internal discontinuities, and though it did have minor porosity spots present, the overall strength and performance of the final casting was not compromised.

## Metallurgical Considerations

Many metallurgical decisions were made with respect to our axe during the design and manufacturing process. The first major decision involved material selection. Originally, the plan was to manufacture the axe head out of stainless steel. However, after further consideration, this material was not chosen due to its increased difficulty in machining and processing compared to other options. Instead, the steel we selected was 8630 for casting the axe head. This material was chosen because Eagle Alloy, Inc. frequently pours this alloy, making it readily available and well understood for casting applications. For our specific batch, additional carbon was added to the ladle in order to increase the hardenability of the material, resulting in a final carbon content of approximately 0.50%. This higher carbon content allowed the material to achieve greater hardness after heat treatment, which is important for an axe that must maintain a sharp edge while still resisting fracture.

Another important metallurgical decision that significantly affected the final properties of the axe head was the quench and temper heat treatment process. After post-processing, the axe head was heated to approximately 1600°F to reach the austenitizing temperature. Once the proper temperature was reached, the axe head was immediately quenched in 100°F water to rapidly cool the material and form a harder microstructure. After quenching, the axe head was tempered in an oven at 350°F for 45 minutes. This tempering step was necessary to reduce brittleness caused by the quench while maintaining sufficient hardness. The quench and temper process increased the overall hardness, durability, and edge retention of the axe head, while still allowing the part to withstand impact without cracking.



## Final Results

The Bulldog Casting Crews axe weights 3lbs and has an overall length of 29.875 inches. It is made out 8630 with additional carbon and has a white oak handle. During the process the team had many moments of learning. From walking around the foundry to learning about the process of gating and pouring. It was eye opening for us as welding engineering students to step into the world of casting whole parts we would think weld together.

## Works Cited

[Horseman's Axe – Arms & Armor](#)

[Arms and Armor Horseman's Axe - Tritonworks](#)

[Horseman's Axe -- myArmoury.com](#)

[Battle axe - Wikipedia](#)