SFSA Cast In Steel 2026
Horseman's Axe Technical Report

Michigan Technological University
Team: The Steel Toed Boots

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A DIVISION OF LAWTON STANDARD

Executive Summary

This report outlines the development of a historically inspired horseman's axe for the 2026 SFSA Cast in Steel competition through the utilization of modern casting technologies. Significant effort was put into the research, design, fabrication, and testing of the axe to meet the specific competition requirements. Taking inspiration from early European designs, the axe underwent multiple iterations through which feature resolution was reduced to improve castability. Magma simulation software was utilized to ensure casting feasibility of the final design.

During alloy selection the team ultimately opted to use AISI 8630 steel, a low nickel, low molybdenum alloy. Material properties which contributed to this selection were the high achievable strength and ductility measurements as well as the material's good weldability. The balance between high strength and ductility would allow for significant energy absorption during impact without breakage. Additionally, AISI 8630 is the steel alloy which is most commonly produced by the foundry partner, Lawton Standard Temperform division. With increased quality requirements for the molten metal there was a decreased possibility of reoxidation inclusions within the final casting, affording our axe with less internal stress concentrators.

The casting fabrication process selected by the team was resin sand casting using 3D printed molds. To improve the as-cast surface quality of the axe, a wash was applied to the internal mold surfaces. Following casting, repairs had to be made on hot tears present in the axe through welding. A heat treating regime was outlined with the assistance from the foundry partner to achieve a final axe with a refined grain size and preferential martensitic microstructure. The processing consisted of normalizing at 1750°F, austenitizing at 1650°F with a subsequent water quench, and a final one hour tempering stage at 800°F.

Final finishing consisted of grinding excess material from the blade, handle, and spikes. Forging was also utilized to increase the length of the handle, improving overall balance of the axe. Special consideration was taken to improve the edge retention of the sharpened blade and spikes. This was accomplished through flame hardening. To provide grip and showcase school spirit and husky pride, black and yellow hockey tape was applied to the axe handle.

Introduction

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 year teams were tasked with producing a Horseman's axe capable of one-handed use. This report documents the steps that Michigan Technological University's team The Steel Toed Boots followed to create such an axe. Background research on the history of the Horseman's axe was completed to ensure the production of a historically inspired casting. Consecutive steps in the axe production were ensuring castability through design and modeling, alloy selection, decision on post cast processes, part fabrication, and final inspections and testing.

Background

Axes have been an extremely important and common tool used for millennia as both tools and weapons, the first shafted axe created around 6000 BCE [1]. Many different early cultures have used their own version of a battle axe, such as much of Northern Europe from the late stone age through the early bronze age, as well as ancient Egypt and many other cultures from around the world [1], [2]. When it comes to warfare, a lighter, more compact design was more efficient for a battle axe [1]. However, some cultures did make axes with rear blades, they were often too heavy and unwieldy for use in battle [1]. A battle axe with a narrow, wedge-like head and beveled edge appeared in common use by the Franks in Northern Europe by the fifth century CE [1]. About the 12th century, many European nobles adopted a variety of single handed battle axes as a horseman's weapon over the sword [1]. During the 14th and 15th centuries, English archers primarily frequently carried small, single bladed axes, essentially horseman's axes, on their belts [2]. There are many different examples of historical figures wielding a horseman's axe, one of the most well known is that of Robert the Bruce during the battle of Bannockburn, in which he slays English knight Henry de Bohun with it [2]. Another great example of a historical horseman's axe is the ornate Horseman's Ax of Cardinal Ippolito de' Medici located in the Metropolitan Museum of Art [3].

There is wide variety in the dimensions of a horseman's axe, but the axe created for the Cast in Steel competition falls within the range of historical horseman's axes. Some horseman's axes have ornate designs, such as the Medici axe [3] and the Spanish axe [4], while many others are plain. Many historical horseman's axes contain spear points on both the top and back of the axe head, while others have a blunt portion, hammer, as the back of the axe head. See Table 1 for specific dimensions. Similarly, the one created for the Cast in Steel competition has a spear point at the top and back of the axe head. Table 1 shows that the horseman's axe made for competition has similar components to historical axes, as well as, for the most part, dimensions within the range of the historical axes. One main difference between the competition axe and the three historical horseman's axes is the weight. The main reason for the difference in weight is the historical axes utilized wood for the handle, whereas the competition axe utilized steel for the handle. On the basis of historical accuracy, the competition axe is quite historically accurate.

Table 1. *Comparison of features and dimensions between historical horseman's axes and the one created for competition [3], [4], [5].*

Features	Italian	English	Spanish	Competition
Back of axe head	Hammer	Point	Point	Point
Tip of axe head	Point	Point	Point	Point
Blade Length	13.3 cm	7.60 cm	18.2 cm	16.5 cm
Total Length	78.1 cm	74.8 cm	N/A	48.9 cm
Weight	1134 g	975.0 g	N/A	1427 g

Design

Cad Design

The designing of the axe was done in Autodesk Fusion and underwent multiple iterations and adjustments before coming to the final design. The first version had a circular cone spike at the back of the axe head and a rectangular spike at the top of the axe head with a large, 9 inches tall, axeblade. The very next iteration saw the replacement of the circular cone back spike for another rectangular cone spike. In the following iteration, the handle was shortened and the axeblade was redesigned to be smaller, both of which were done to decrease the weight and improve historical accuracy. The rectangular cones were replaced in favor of circular cones in the next version. In the final iteration of the horseman's axe, the extremities of the axehead were increased to a minimum of a quarter inch thick and all of the edges were fileted, both of which were done to greatly improve the castability of the axe.

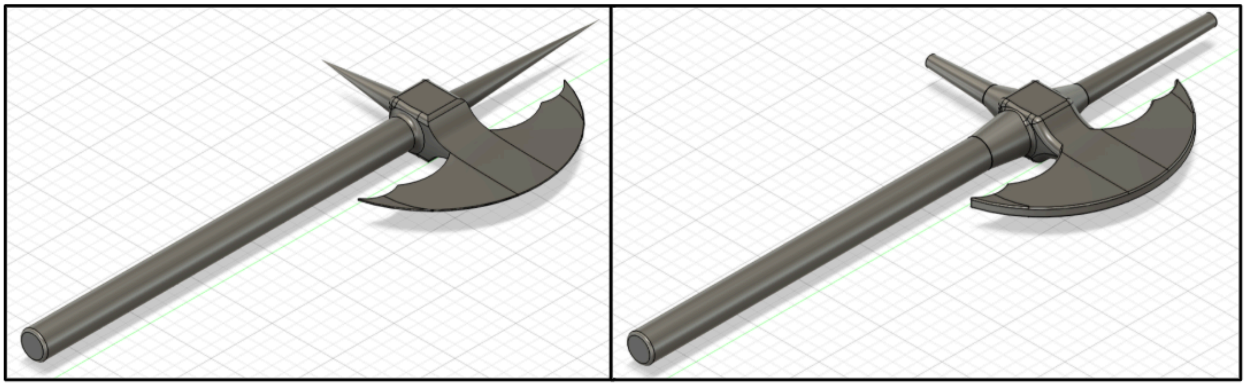

Figure 1. *Model of axe before and after thickening axe extremities*

Alloy Selection

During the alloy selection process, a range of steels were evaluated (Table 2). These alloys were selected for consideration due to their high tensile strength, excellent ductility, and good castability. A low carbon composition of less than 0.6 wt% was specifically recommended to ensure adequate ductility. High ductility is critical for the horseman's axe, as it enhances energy absorption and promotes plastic deformation under applied stresses, thereby reducing the likelihood of rapid brittle fracture.

The material ultimately selected for the horseman's axe was a low–nickel, low–molybdenum steel, commonly known as AISI 8630. This alloy provides a desirable balance of mechanical properties, including a yield strength of approximately 550 MPa and an elongation of 16% at fracture [6]. Additionally, this material exhibits good weldability, making it well-suited for repair if necessary.

Table 2. *Summary of alloy selection.*

Material	Description
1050	Medium carbon steel
4140	Low-alloy Cr, Mo steel, better ductility than 4340
4340	Low-alloy Cr, Mo steel, higher strength than 4140
5160	Cr, Mn alloy steel with the addition of Si
8630	Cr, Ni, Mo alloy steel

Post Cast Processes

High hardenability was also a critical consideration for the horseman's axe, as the material must retain a sharp edge under repeated impact. This was achieved through a heat treatment schedule consisting of normalizing, austenitizing, quenching, and tempering. A normalizing step at 1750 °F was first employed to refine the grain structure, thereby improving strength and toughness. This was followed by austenitizing at 1650 °F and subsequent water quenching to form a martensitic microstructure. The material was then tempered at 800 °F for one hour to enhance ductility and reduce internal stresses.

Temperatures in the range between 450–800 °F were avoided due to the risk of martensite embrittlement. As a result, the higher temper of 800 °F was selected to achieve better ductility. However, this higher tempering temperature imposed a risk to the blade's edge retention. To address this, the blade edge and spike regions were selectively flame hardened using a torch followed by an oil quench, thereby increasing surface hardness of those areas.

Fabrication

The mold for the horseman's axe was 3D printed using sand and resin layers. A mold wash was applied to the mold for a better cast surface condition. The 8630 was cast at 2912 °F. Once the axes were cooled, they were knocked out of the molds. However during this process some hot tears were found. To remediate this issue welding was performed prior to heat treatment, ensuring that no voids were present at the interface and that the weld material is homogenized with the rest of the material. The risers were cut off before the heat treatment process.

After the axe was cast and heat treated, excess material left by the gating and risers was ground off as much as possible by the Lawton team. Once the swords were received by the MTU team, further grinding with an angle grinder and sand belt grinder was done to minimize excess material left on the axe. The axes were also lengthened by forging out the handle this lengths the overall axe and improves the strength of the handle due to the elongated grains. Once this was done the tips of the spike and blade edge were flame hardened. While this process was performed a layer of oil was baked on the rest of the axe to form a corrosion resistant layer and to add to the aesthetics of the axe. A layer of hockey tape was applied to provide grip to the handle.

Inspection/Testing

In addition to the axes, two test bars with dimensions of 1 × 1 × 12 in. were cast for inspection and evaluation. Optical emission spectroscopy (OES) was conducted on an as-cast test bar to determine the chemical composition of the alloy (Table 2). The test bars were then subjected to the same heat treatment schedule as the cast axes.

Table 4. *Elemental composition of alloy via OES*

C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Al	Ti	Co
0.3100	0.4912	0.6909	0.0107	0.0236	0.4863	0.4877	0.1456	0.1741	0.0173	0.0020	0.0071

Following heat treatment, one test bar was sectioned, and the cross-section was prepared using standard metallographic techniques. The sample was subsequently etched with 3% nital to reveal the resulting microstructure (Figure 2).

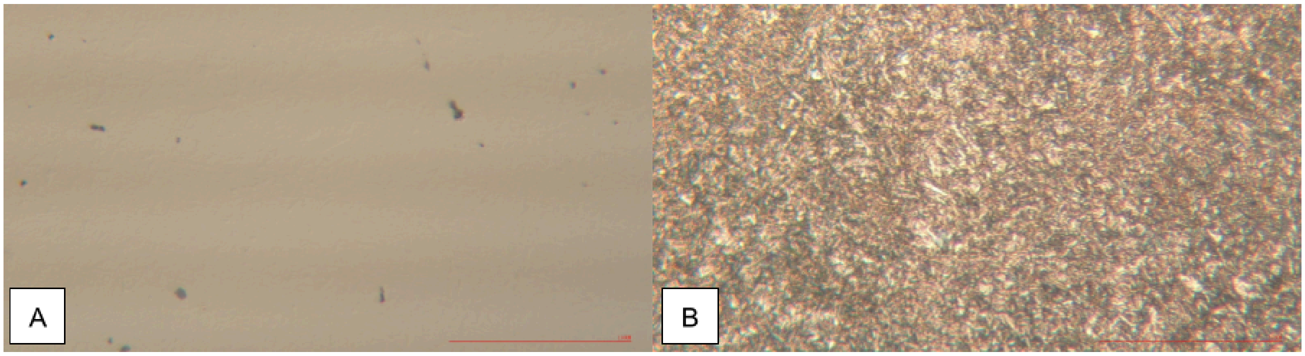

Figure 2. *Optical images (scale of bar 100 µm) of axe alloy after heat treatment (800°F temper). Microstructure prior to (a) and after etching with 3% initial (b).*

Final Product

The final length of the axe was 19 inches meeting the requirement of being less than 34 inches. Additionally, it meets the weight requirement being approximately 1.4 kg. The horseman's axe has a top spike that is 5 inches long and a back spike that is 3 inches long with an axe blade that is 6.5 inches long. The-Steel-Toed-Boot's axe is well within the competition requirements. Figure 3 shows the final axe.

Figure 3. *Finalized Horseman's axe.*

References

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