SFSA Cast in Steel 2026 - Horseman's Axe
Technical Report

Grand Valley State University - The Axecutioners

Team Members:
Matt Cronk
Aleena Curry
Mason Leenheer
Rock Phelps

Faculty Advisor:
Dr. Abishek Balsamy-Kamaraj

Sponsors
Eagle Alloy
Hansen Balk

Acknowledgements:

The Casting Club would like to thank all of the key individuals and groups whose contributions made our team successful. First, we would like to thank Mr. Jason Klein, Mr. Jason Bergman, Mr. Josh Gerrans, and Mr. Nic Tarzel from Eagle Alloy, along with Eagle Alloy Inc. and Hansen Balk Steel Treating Co., for their work in developing our sword. We thank Caleb DeBoer, Dalton Jones, and Nic Gunnink for lending expertise and resources. We would also like to thank our faculty advisor, Dr. Abishek Balsamy-Kamaraj. We would also like to thank the School of Engineering at Grand Valley State University for its facilities and financial support.

Table of Contents:

Executive Summary

The Grand Valley State University (GVSU) team, The Axecutioners, created a horseman's axe with inspiration from the period of 1314. The primary method of manufacturing for creating the axe was casting, and it was cast in AISI 8640 steel that was alloyed up to an ANSI 8650. Other materials used to create the axe include ash and leather. A significant amount of post-processing was done to the cast parts, such as heat treatment, grinding, polishing, sanding, and sharpening. The axe measured 26in overall and weighed in at 2.85lbs.

1. Introduction

The 2026 Cast in Steel competition objective was to create a horseman's axe that centers around the period of 1314, following Robert the Bruce, King of Scotland, as a reference point for axe design. The Steel Founders' Society of America (SFSA) created this competition to encourage students to learn more about the process of casting steel products and to observe the latest technology used in steel casting. The Horseman's axe design specifications included a weight restriction of 1.5 kg (3.3lbs) and a total length of the axe being no more than 800mm (31.5in).

The Horseman's axe has been the weapon of choice for mounted soldiers since the Middle Ages. But these axes were not just weapons; they were also ornamental pieces. The Axecutioners based their design on axes around the period of the Scottish Civil War. These axes were known for their crescent-shaped blade for chopping and their opposing spike used for piercing armor. The combination of these created a versatile weapon that could deliver both crushing and piercing blows to an enemy.

2. History

The horseman's axe was developed alongside the tradition of Highland warfare and mounted raiding culture. During the late medieval period, Scottish clans frequently engaged in various border conflicts and raids. Warriors needed a weapon that could be wielded quickly while controlling a horse, leading to the use of lighter axes with a shorter haft and a forward-weighted head. The axe was extremely effective in close-quarters engagements, allowing riders to deliver powerful downward and lateral strikes against armored opponents.

As warfare in Scotland evolved through the 16th and 17th centuries, units became more organised, particularly during conflicts such as the Wars of the Three Kingdoms. While early firearms and swords gained increasing popularity, axes continued to serve as practical secondary weapons and field tools. The utility even spanned beyond combat, as soldiers commonly used them for clearing paths and for general survival tasks during treks through rugged terrain. This reinforced its usefulness in combat and, even more importantly, its practicality in the field.

By the 18th century, traditional horsemen's axe-like weaponry began to decline in military relevance due to the widespread adoption of standardized firearms and changing battlefield tactics. Despite this decline, the design remained significant as an example of equipment shaped by the mechanical and practical constraints of mounted combat. Its evolution reflects how Scottish warriors balanced striking effectiveness, weight distribution, and multifunctional utility in response to mobility demands and environmental conditions. As a result, the horseman's axe provides a useful historical case study in the relationship between weapon design and shifting technological requirements in warfare.

3. Metallurgical Considerations

The metallurgical considerations for the axe are important because the material choice can dictate behavior and strength. Properties that need to be considered for the axe include yield strength, modulus of elasticity, the hardness of the material, and compressive strength. The yield strength of a material is used to determine the stress that an object can withstand before it experiences deformation. If the stress levels stay beneath this point, the material will return to its original form. If it exceeds it, it will be permanently changed. The modulus of elasticity is an important factor for the axe because it signifies how elastic the material is. In addition, hardness is significant because it will affect the blade's edge and how sharp it will be after striking an object. However, the material can't be too hard, or it will be brittle and not be elastic enough.

3.1 Steel Selection Process

8640 steel is a strong metal composite that is known for use in high-stress applications commonly found in combustion engines. It is also commonly used in automotive industries, aerospace industries, and heavy machinery applications. This is because of its high durability, and when heat-treated, it becomes incredibly durable and strong. Since 8640 is commonly used within the industry that requires materials capable of handling high stress and strain environments, it was decided that 8640 was the material to go forward with. With a medium carbon blend, it lends itself more to strength and leaves edge retention in maintaining a sharp to be more difficult to attain. To see the composition of the axe head, see **Figure 1** in the appendix.

4. CAD Model

The computer-aided design (CAD) model of the axe was done using SolidWorks.

5.1 Initial Design

The initial design for our team's horseman's axe was inspired by the anchor logo that Grand Valley State University has. It was then further modified to achieve what we believed the testing would center around. We assumed there would be a portion of the test centered around penetration, which led to our rear pike. The pick was also designed to look like a bird's beak in an attempt to alleviate stress during puncturing activities as well as penetrate deeply without the pick getting stuck. The main blade portion of the axe was shaped with the intent to try to keep the anchor hooks from traveling too far from the center mass in case of fracture/failure.

5.2 Design Alterations for Castability

When an initial design had been reached, the team started discussions with the foundry to start making our idea successful. The adjustments and modifications that were made were seen at various stages of the design process. These adjustments had taken place even at the beginning of the process, as the amount of material that was on the sides of the eye of the axe was too thin to reliably get a high-quality pour while still maintaining the strength that we required. The feedback from the foundry was to add more fillets and more material to leave room for gating and cooling with minimal porosity.

6. Casting Process

The CAD model was 3D printed and screwed to the bottom of a mold in **Figure 4**. The molds were filled with airset sand and vibrated to get all of the airset to settle in the mold. Once the molds were settled, they were set aside to harden. Once hardened, the molds were flipped upside down shown in **Figure 5** and scored in various places so that air could escape when the steel was being poured. Pressurized air was sprayed across both mold surfaces to clear debris from them. The top and bottom molds were connected and sealed using an adhesive with an entry hole for the molten metal in **Figure 6**. A paper towel was glued over the top of the entry hole, and weights were placed on top to keep the mold secure. Finally, molten metal was poured into the molds from a ladle seen in **Figure 7**.

7. Getting to Size

After receiving the castings back from Eagle Alloy, the team planned to cut off and refine the castings into properly sized axe heads. Of this multi-step operation, the first plan of action taken was to remove the gating that was still on the axe. Then the next process was to spend time getting to make sure the grinder and axe head were properly acquainted, multiple hours were spent shaping the provided heads into the slim and pointy heads. After grinding the selected few that looked nice, it was found that all of the heads had a small air pocket along the top of the spine of the spike. How we approached that issue was by Tig welding the air pocket to fill in the gap within the back spike.

7.1 Handle manufacturing

The first step into making the handle was deciding what wood to use. This was done by creating multiple test pieces of the same length and diameter and running multiple experiments to figure out which one was the most optimal. One of the tests was hitting the wood samples against an anvil five times and noting the damage. Another test was attaching an axe head to each and hitting the anvil again three times to see the damage if the person swinging the axe missed the target. After inspecting the damage, there were dents in both the ash and hickory wood; however, there was less damage on the ash. In addition, both wood types had some splintering, although the hickory wood was prone to cracking. For this reason, the team decided to go with ash for the handle of the axe.

The wrap style used on the handle is Tsukamaki, which is Japanese for handle wrap. Tsukamaki is most commonly found on daisho swords, which fall into the sub-categories of daito and shoto swords, daito's (outside swords) being katanas, and shoto's (inside swords) being wakizashi (similar to a short sword) and a tanto (similar to a dagger). One difference between the authentic Tsukamaki wrap found on those swords and the Tsukamaki found on our axe is how it was tied off. In a traditional Tsukamaki there is a hole in the bottom of the hilt allowing for an intricate weave to pass between each side. Our axe not having a hole in the bottom forced us to get creative in tying off the wrap. The decision to add the lanyard at the end of the hilt is also a creative difference from traditional Tsukamaki wrap, but it was done because it visually brings the piece together.

7.2 Heat Treatment

The plan for heat treatment was to have our foundry, Eagle Alloy, perform heat treatment on a fraction of the cast axes, and for the remaining heads to be dispersed between our own attempts at heat treatment, as well as sending them out to other companies for professional heat treatment.

Heat treatment for the final selected axe head was done by Hansen Balk. The heat treatment was performed at a quench at 1750 degrees Fahrenheit, then something at 325 degrees Fahrenheit.

7.3 Polishing and Sharpening

The process of polishing and sharpening the axe is done in progressively smaller steps. The initial product is bulky and has extra material. A series of fine to finest grits of sandpaper were used to bring the axe down to size, and then make it smooth and shiny. Since there is no sharp edge to begin with, the edge and spike gradually got sharper as the sandpaper got finer.

7.4 Engraving

The process for the application of the engraving was through the use of electroetching. To perform the etching process, the materials used were a power supply, copper wire, and a high salinity tub of water that could comfortably fit the axe head. The first step to the process was to paint the axe head fully so that there was no exposed metal on the surface of the axe. Then, with a stylus (or anything sharp), the paint was scratched off of the axe head. Following scratching off the desired engraving, the part was suspended via copper wire over a bucket of salt water. The positive lead was attached to the axe head, and the negative lead was attached to the water. Through this process, the team was able to eat away thin layers of metal over the course of 3 sets of 5-minute waiting times. After removing the axe from the etching vat, it was cleaned with acetone. The final engraving image is provided in **Figure 8.**

7.5 Assembly

The axe assembly is made up of four main pieces. These include the axe head itself, the wood handle, the wedge, and the leather wrap. The ash handle was stained and had black leather straps wrapped around the bottom. The axe head was put on the other end of the handle and secured by cutting a line and placing a wedge within the line. This prevents the axe from coming off the handle while in use.

7.6 Testing

The testing process for our axe is composed of progressive tests aimed at identifying the axe's overall durability and sharpness. The testing began with checking sharpness by cutting various fruits and vegetables. The axe sliced cleanly through everything thrown at it. Next, the axe's spike was tested. A sheet of aluminum was set up in a way that the spike of the axe could be utilized. After striking the sheet, the metal immediately mushroomed on the backside of the sheet, and a two-inch hole was left behind. Refer to **Figure 2**. After inspecting the damage, there were no signs of deformation or a rolled edge on the spike. Further testing was performed to identify the limits of the horseman's axe, using a steel plate. First, the plate was punctured using the spike(as seen in area labeled #1), followed by a slash from the blade(as seen in area labeled #2). Refer to **Figure 3** to see the results. As for strike #1 using the spike, similarly to the previous test, the edge held with no deformation. For strike #2, it was expected to see some major issues with the edge, but that did not occur. Again, there was no deformation of the blade.

Upon further inspection of the axe head, there was a slight shift in where the axe head sat in reference to the handle. After seeing this, testing was stopped to revisit the bond between the head and the handle.

One of the reasons believed to contribute to the blades' instability was the lack of epoxy used in the wedge. After this realization, the final axe was adjusted to make sure that epoxy was placed inside the wedge, and between the eye of the axe and the handle, to ensure extra toughness. Overall, this was some of the toughest testing placed on the schools' SFSA competition submission to date

8. Conclusion

The material used in GVSU's Axecutioners axe was AISI 8640 steel. The product resembles a horseman's axe with the long handle wrapped in leather, while containing characteristics that represent the school, such as an anchor-like shape, the logo, and the clock tower. Challenges of this project include making the axe head castable and within the competition limits, and finding the right material for the wood used for the handle. The method of finding the most suitable wood included making miniature handles and having them go through a series of tests similar to what the real handle would experience during the competition.

9. References

"Battle Axe." Wikipedia, the Free Encyclopedia, Wikimedia Foundation, Inc, 24 Mar. 2026, en.wikipedia.org/wiki/Battle_axe. Accessed 27 Mar. 2026.

Metal Zenith. "8640 Steel: Properties and Key Applications." Metal Zenith, 17 May 2025,metalzenith.com/blogs/steel-properties/8640-steel-properties-and-key-applications.

Ohlmeyer, Jane H. "English Civil Wars." Encyclopedia Britannica, 30 Sept. 2025, www.britannica.com/event/English-Civil-Wars.

10. Appendix

B	C	Al	Si	P	S	Ca	Ti
0.0012%	0.4871%	0.0442%	0.4019%	0.0206%	0.0040%	0.0001%	0.0395%
V	Cr	Mn	Co	Ni	Cu	Zn	As
0.0100%	0.4737%	0.6323%	0.0044%	0.5500%	0.0559%	0.0055%	0.0027%
Nb	Mo	Sn	Sb	W	Pb	Bi	Fe
0.0082%	0.2076%	0.0037%	0.0043%	0.0011%	0.0033%	0.0001%	97.0393%

Figure 1: Metal Composition |8640|

Figure 2: Aluminum Sheet From Testing

Figure 3: Steel Sheet From Testing

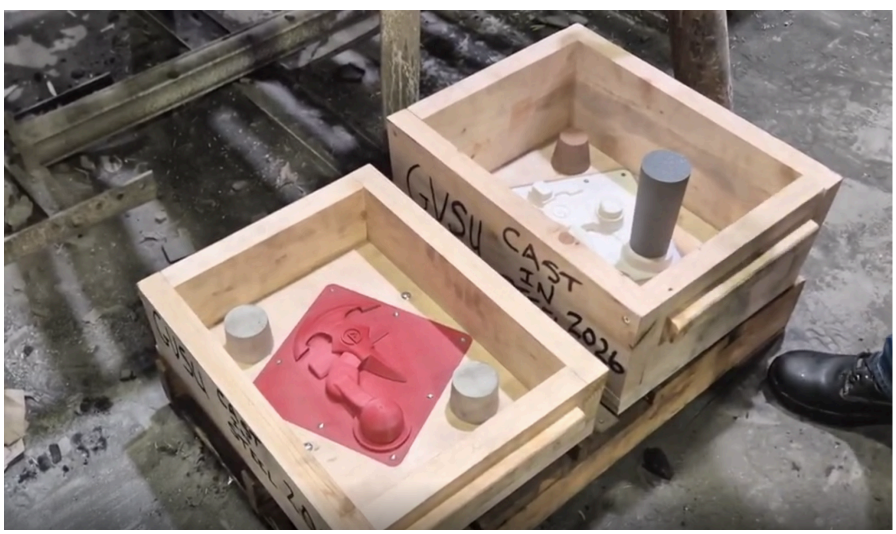

Figure 4: Axe Molds

Figure 5: Airset Sand Hardening

Figure 6: Mold Assembly

Figure 7: Metal being cast into the Mold

Figure 8: Electro-Etching Engraving