

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

California State Polytechnic University, Pomona – Headless Broncos



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1. Executive Summary

The Steel Founders' Society of America (SFSA) has facilitated this competition to teach aspiring students about the casting industry. From the initial design phase to casting the part, the students will have to work together to manufacture their workpiece with the aid of an industry partner. SFSA's 2026 Cast In Steel competition challenges students to design and manufacture a one handed horseman's axe.

The horseman's axe had to fulfill specific purposes when wielded by a knight on horseback. With the improvements of armor within the armies around the world, there needed to be a weapon that could deal damage to enemies protected by steel. Using the momentum of a horse, the axe could be swung to deal great damage against those in the battlefield. The pick on the opposite side of the axe could be used to pierce armor against unsuspecting foes. Its compact design made it a great weapon of choice for cavalry.

There were many iterations of the axe blade designed with Solidworks. The blade was the main focus, with it being presented to many colleagues to get their opinion. When the team was satisfied with the final iteration, it was 3D printed and given to Soundcast Co., Headless Bronco's wonderful industry partner that specializes in sand casting. After that, it was heat treated and returned to the team to sharpen

The axe weighs 3.2 pounds and is about 24 inches long, cast with a carbon steel alloy and has a handle wrapped in leather. The entire axe is cast in 4130 carbon steel. The team aimed to design an axe that would win the practical portion of the competition, with the aesthetics being reminiscent of a haunted weapon. The leather wrap was also painted to give a theme of royalty as well.

2. Introduction

2.1 Objective and Constraints

At a fundamental level the edge of an axe needs to be a sharp piece of metal that can cut things. However, there are a multitude of factors that need to be considered. The axe needs to be light enough to be properly wielded with one hand, short enough to be safely swung, balanced correctly to not injure the wielder, be sharp enough to cut through obstacles, durable enough to not shatter on impact, hold an edge after use, be aesthetically pleasing, and adhere to the guidelines set by SFSA for the competition. These constraints stack up fast when considering how much overlap they have and considering the cost to develop and implement them, both in time and cost.

The SFSA guidelines listed a blade that weighed less than 1.5 kg (3.3 lbs) and 800 mm (31.5 in). The weight is a safety concern, since wielding a one handed axe that is too heavy can easily sprain the wrist with the twisting motions. Aside from competition requirements, there are basic performance requirements as well. To hold an edge well, the axe needs to have strong hardness. This leads to the next point: durability. The axe needs to straddle the line between having high hardness and high ductility. If the blade is too hard it becomes brittle and will shatter

upon use, if it's too soft, it'll bend and not cut anything. Having the best of both worlds means a sturdy axe that will hold an edge and survive multiple rough swings without shattering.

2.2 Literature Review

The axe is a staple tool that has been around since roughly 6000 BC. While the axe in broad terms had many uses, the horseman's axe stems from battle axes that were popular in Europe during the late Stone Age and early Bronze Age. These early battle axes typically contained two parts, being the axe head and the wooden haft serving as a handle. The axe head was typically made from stone and attached to the haft via wedging, flanging, winging, or socketing. As metalworking became more popular in the Iron Age (roughly 1000 BC), these designs better reflect what axes look like today. During this time, the axe head typically had one wedge-shaped convex blade side with a sharpened edge that tapered into a blunt pick. The haft during this time was also constructed fully out of metal and had small holes near the bottom to accommodate leather grips. This axe design was useful for many reasons, mainly being the weight distribution. The long length of the haft (often up to 3 feet) and the weight of the head gave the wielder an optimal weight distribution to be able to effectively be used one-handedly. The pick of the axe was also useful for weight distribution, as most of the head weight lay in the blade; more downward momentum could be created when striking. This focus on optimal weight distribution makes perfect sense, since the axes were used mainly one-handedly and needed enough force to break through an enemy shield or their armour. Some axes also feature very short hafts, and were able to be thrown upwards of 40 feet, typically at the very start of a battle. These axes were also primarily used on horseback during wartime, hence the name "horseman's axe". These battle axes slowly fell out of favor, but were still being used as late as the 16th century, until they were eventually upstaged by an array of swords.

While the design for the horseman's axe stayed very similar over time, there have been many noticeable changes to affect efficiency. One of these changes includes the angle of the haft. Instead of the traditional straight haft, some axes opted for a haft that was slightly convex towards the blade for a better swing. Additionally, as time moved on, warriors noticed the usefulness of the butt end of the head where the pick is. They found that with a slightly blunt pick, they were able to get many uses out of it, mainly comparable to those of a hammer. This butt was also proven useful to help puncture impenetrable armor. Another big variation in these axes comes from the often 6-inch spike protruding out of the top of the axe head. While this stabbing function was most useful for delivering the final blow to an enemy, the design choice fell out of favor quickly.

The horseman's axe is, at its core, a very primitive tool that has had a place in various cultures for thousands of years. That is why our design opts to pay homage to that simplicity, while also adding some design flares that were typical of the time. Our axe uses an all-metal design, which consists of both the head and the haft, which is consistent with many horsemen's axes in the Iron Age when they were peaking in popularity. Our design also includes a leather grip, which was a very common add-on for ease of carrying. We colored our grip purple both to be consistent with our team name and theme of "headless broncos", but also to pay homage to the use of color as a symbol of identity and status. Overall, our design reflects a balance between historical accuracy and modern interpretation, preserving the functional principles that

made the horseman's axe effective while incorporating stylistic elements that represent our team. This combination allows the piece to serve not only as a functional casting project, but also as a representation of the evolution and enduring significance of the horseman's axe

3. Design

3.1 Axe Design

3.1.1 Handle

For the handle, the conclusion was a simple, functional, and desirable weapon that will also succeed in all possible performance tests. An all metal axe includes the challenge of making a handle that is comfortable. The team also envisioned a handle that would be wrapped in a purple leather to give an air of royalty to it.

As a sidearm and integral weapon for a knight on horseback, it was important to get the design right. The main guideline we went with was a handle that was similar to that of a splitting axe. This idea was further developed by enhancing the grip to feel more comfortable with a center of mass higher up the shaft. Thus, the final design (*Figure 3.1.1*) leads to a handle that has an indication of where to hold it, as well as a shape reminiscent of a hammer.

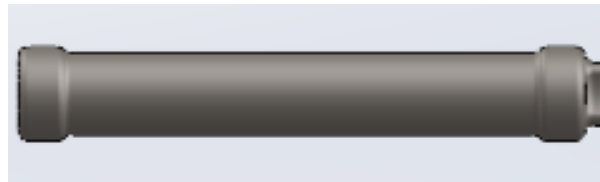


Figure 3.1.1: Final iteration of handle.

3.1.2 The Shaft:

The design of the shaft had two goals in mind. It had to be strong enough to withstand harsh force and it had to be lightweight enough to be within the parameters of the competition. After lengthy discussion and research, the design team settled on an I-Beam design. With this design, we would be able to withstand a great amount of force while eliminating any material that would add on to the weight. The final design (*Figure 3.1.2*) is perfect for high impact and will help deal a powerful blow.

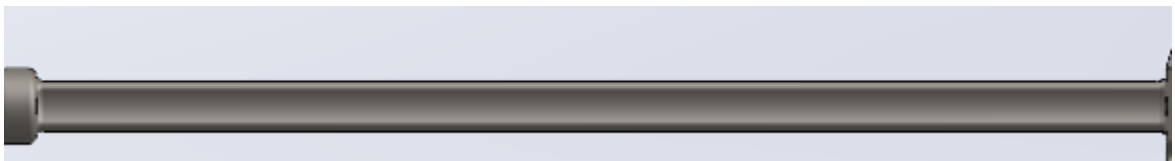


Figure 3.1.2: The I-Beam design.

3.1.3 Axe Head Design

The axe head was designed with performance in mind. With the majority of the testing being against hard objects, it was clear that the edge of the axe took a lower priority. Along with the main blade of the axe, we also had to think about the pick that was perpendicular to the shaft. The final design (*Figure 3.1.3*) uses fundamental geometry to ensure that any head-on collision would prove no risk to the axe.

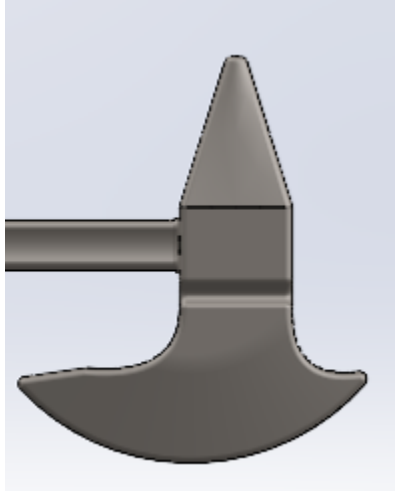


Figure 3.1.3: The axe head and pick.

3.2 Design Selection

There were several designs in the running for our axe. Some (*Figure 3.2.1*) leaned heavier into the team's namesake of the haunted horseman. While others (*Figure 3.2.2*) had a different vision of the blade design. After deliberation and a refocus on what the goals were, the team settled on our final design for pure performance.



Figure 3.2.1: One potential design.

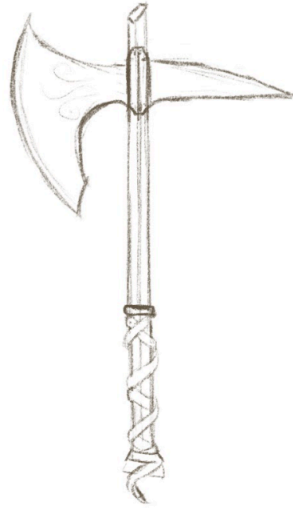


Figure 3.2.2: Another sketched version.

4. Manufacturability

4.1 Alloy Selection

Team Headless Broncos conducted extensive literature research and discussed the key features in selecting an optimal steel alloy for the axe. The list of potential alloys was reduced to the top three tool steel materials: 4140, 4130, and A2 specialty alloys.

A2 alloy is a high-carbon tool steel that is used for versatile applications, such as tooling, automotive, and aerospace. It goes through a cold-working, air-hardening process, and the chemical composition provides the highest hardness range and corrosion resistance out of the top three alloys. However, A2 alloy is brittle and the least suitable for the impact resistance features of an axe, which can be a challenge for metal casting and machining. Its lowest toughness range and highest hardness range do not meet the team's desired specifications.

ASI 4140 is a low-alloy carbon steel that has practical applications within the defense and aerospace industry. It is commonly used to manufacture gears, shafts, or even structural components. It goes through a heating treatment during hardening, before it is air-cooled. The metal offers an excellent balance of strength and weight, which offers higher durability in high-stress applications. While the metal is cost-effective and easy to machine, it is also not an easy metal to work with, as it has low corrosion resistance, which makes it more susceptible to the elements. The high impact resistance is overkill on the axe, as edge durability is not as strong, which makes it dull faster when applied. While ASI 4140 has a higher impact resistance compared to A2 steel, it would not suit the composition of the axe.

ASI 4130 is a low-alloy carbon steel similar to 4140, with some differences that cemented our team's final choice for the axe. The axe is mostly composed of iron, but the chromium and molybdenum act as strengthening agents for the steel. The material is also used for similar applications in manufacturing structural parts and gears. But it is also more commonly used to create cutting tools. The metal responds better to heat treatment, which allows the steel to be welded into a more durable form without adding too much weight. When creating a

sharper edge, it is tough enough not to break on impact while also leaving room for malleability for the axe to cut through most objects. While ASI 4130 suffers from similar issues to 4140, the steel is more malleable and well-balanced to be used in forging cutting tools such as our axe. This makes the selection our final choice for which material our axe should use.

A materials trade study and failure analysis were conducted to determine which of the three top alloys best suited the specification of the team’s axe (See Figure 4.1.1). This resulted in the 4130 steel alloy being the optimal material. The specialty alloy is commonly used to make cutting tools, which fit the criteria of our creation.

Top 3 Alloy Materials					Ranking	Reasoning
					1	Unacceptable
					2	Less preferred
# 1:	4140				3	Indifferent
# 2:	4130				4	Preferred
# 3:	A2				5	Most Preferred
Criteria	Castability	Elongation	Yield Strength	Hardness (50 - 55) HRC	Corrosion Resistant	Results
# 1:	5	4	4	4	3	960
# 2:	4	3	5	5	5	1500
# 3:	3	4	4	3	5	720

Fig 4.1.1 FMEA Analysis of 4140, 4130, and A2 steel alloys

4.2 Manufacturing Processes

The manufacturing process for this axe is rather simple. First, the axe was designed in SolidWorks. After casting the simulation, the gating system was confirmed and finalized. Then the patterns were 3D printed and sent to Soundcast Co. for the sand casting process. After casting, cutoff and heat treatment occurred. When all was done, the axes were sent back to us for grinding and post processing.

5. Quality and Performance

5.1 Chemical Composition

Understanding the chemical composition of steel alloys is crucial to selecting the optimal material for the axe. The table in Figure 5.1.1 displays the chemical makeup of the 4130 steel alloy. It has a high iron level that is reinforced with chromium and molybdenum, which is well-balanced between hardness and toughness. The use of chromium increases its ability to withstand wear and tear and improves corrosion resistance. The Iron composition acts as the main structure for the other metals to bond with so that it is held together with little resistance. There is a moderate level of molybdenum, which enhances the alloy’s hardenability and resistance to thermal fatigue in high-temperature settings.

Steel Alloy	Requirement	Fe	Cr	Mn	C	Si	Mo	S	P		
4130	Min. %	97.03	0.80	0.40	0.28	0.15	0.15	-	-	-	-
	Max. %	98.22	1.10	0.60	0.33	0.30	0.25	0.040	0.035	-	-

Fig 5.1.1 Chemical Composition of ASI 4130 Steel Alloy. Table referenced from ASTM A322

5.2 Inspection and Testing

Our foundry sponsor was generous enough to give us 4 axes (*Figure 5.2.1*) to choose from and keep. After inspecting all the axes for any defects or unexpected curves, we chose the most aesthetically pleasing one. After settling on our main axe, we used the others to test and really push our design to the limit.

Once we tested our method of sharpening, we decided to do a multitude of tests. The focus of these was to see how our edge holds up after contacting blunt objects as well as see how well the pick could hold up. After that, the team used fruit to really get a feel of the power behind our axe.



Figure 5.2.1: The four axes of the apocalypse.

6. Final Product

6.1 Basic Requirements and Uniqueness

With the basic performance requirements addressed, unique aspects can be brought up. The finish that sand casting produced was something we are very happy with. The look of the steel makes the axe seem experienced. The leather wrap being purple indicates that only

venerated knights could wield it. Its glossy finish can catch the light in a way that turns everyone's head.

7. Improvements

After reviewing the overall design and manufacturing processes of the axe, our team settled on some improvements. One improvement discussed was focusing more attention to the aesthetic details of the axe head. Drafting additional and realistic iterations will provide various ideas that display the level of cohesion to unify the designs smoothly.

Another improvement that could be made was to hone our design of the blade. Although the focus was to make sure that the edge would not curl, a better edge geometry could save weight while achieving the same goal.

8. Conclusion

Team Headless Broncos consists solely of students progressing through their undergraduate degree who are using it as a learning experience first and foremost. This competition allowed every member to turn their book academics into practical knowledge, to see how products are manufactured in their entirety. The team rose to the occasion every step of the way to prove they have what it takes to make it in the industry. They designed the axe, modeled it in CAD, successfully partnered with a foundry to cast it, heat treated it, sharpened it, and sent it to Michigan for the competition as a successful cast. They did it all with help from each other and contacts they networked while participating in the competition. This task was far from easy, but that didn't matter to them no, what mattered was the experience, the knowledge, that was the goal. It doesn't matter who wins the competition or not, but who stands there.

9. Acknowledgements

We would like to express our gratitude to Dr. Victor Okhuysen for his unconditional support, which ensured the successful completion of our project. We are deeply grateful to our industry partner, Jason and the Soundcast Co. team for their expert guidance throughout the design and manufacturing processes of our team project. We also appreciate their generosity in allowing us to use their facilities to manufacture our axes.

We are eternally grateful for the time everyone has taken out of their busy schedules to mentor us in our project for the SFSA Cast in Steel 2026 Competition in Grand Rapids, Michigan. This experience has provided us with invaluable educational and industrial insight, significantly contributing to preparing our future professional engineering careers.

10. References

“The Battle-AX.” *Warfare History Network*, 29 Jan. 2026,

warfarehistorynetwork.com/article/the-battle-ax/.

Conniff, Megan, and Audrius Zidonis. “4140 Alloy Steel: Composition, Properties, and Industrial Applications.” *Xometrys RSS*, Xometry, 19 Mar. 2026,

www.xometry.com/resources/materials/4140-alloy-steel.

Instruments, From TA, From Dectris Ltd, From Micro-Epsilon, From Orton Ceramic Foundation, et al. “Aisi 4130 Alloy Steel (UNS G41300).” *AZoM*, 19 Aug. 2019,

www.azom.com/article.aspx?ArticleID=6742.

Instruments, From TA, From Dectris Ltd, From Micro-Epsilon, From Thermo Fisher Scientific – Electron Microscopy Solutions, et al. “A2 Tool Steel (UNS T30102) - Air-Hardening, Medium-Alloy, Cold-Work Steels.” *AZoM*, 11 June 2013,

www.azom.com/article.aspx?ArticleID=6218.

Instruments, From TA, From Dectris Ltd, From Micro-Epsilon, From Thermo Fisher Scientific – Electron Microscopy Solutions, et al. “Aisi 4140 Alloy Steel (UNS G41400).” *AZoM*, 18 Dec. 2019, www.azom.com/article.aspx?ArticleID=6769.

McClements, Dean. “4130 Carbon Steel: Uses, Composition, Properties.” *Xometrys RSS*, Xometry, 14 Oct. 2024, www.xometry.com/resources/materials/4130-carbon-steel.