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

California State Polytechnic University, Pomona – Bronco Knights

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1. 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.

From learning about casting skills to understanding the profound context of the weapon being cast. It is a great honor to undergo the process of casting and learning real world applications that can be helpful in the future. This competition allows us to put our skills and knowledge to test. While also granting us a great learning experience. This competition allowed us to see and reach our true potential when it comes to working together as a team. Learning the hardships and struggles and what it means to put our best selves forward.

Throughout this process, we understood the great feat we are trying to accomplish. From researching, planning, and executing our ideas to reality. Each step of the process was taken with great care. The summary throughout this report will reflect the details and great lengths for the horseman's axe.

2. Historical Context:

The Horsman's axe was mainly used by horsemen (as the name implies). These weapons mainly serve as a last resort when their main weapons were not in use or lost in battle. Axes themselves have been used for a long time throughout history.

When encountering an armored enemy a sword may do the trick. However, since it has limited capabilities of dealing damage against armored enemies. Sword users will be limited to slashing and piercing which has little to no effect against armor. With an axe, there are many opportunities to damage armor. Due to its crescent axehead shape it will damage a small area, as well as open for other moves for a knight. Axes were mainly used by Scandinavians, the Franks, and Danes. They were common amongst the medieval armies of Europe. They were cheaper to create compared to swords as well as versatile when it comes to their designs.

Design wise what's common is the axe head to have a crescent shape as well as a handle that can be suited for one or both hands of the user. There are many iterations of an inclusion of the spike from being on top or behind the axehead. Axes were a tool as well as a main weapon for some, the inclusion of these features allows users to gain an edge in battle. For a horseman's axe that is an entirely different story altogether.

The horseman's axe is seen as the ultimate tool for any calvarymen. The axe was able to wield with one hand with addition of a large spike behind the axehead to swing. Once paired with a horse, you have a metal spike that is speeding towards unfortunate armored people. A spike on the top of the axehead was used as puncturing armor. Making it a good alternative to a lance or spear when charging head on in a battle.

The horseman's axe was the ultimate "jack of all trades" type of weapon on the battlefield. But of course, there are some limitations of the weapon, such as the spikes can be heavily damaged when encountering different surfaces. Losing their sharpness. Since they are on horseback, axes needed to be shorter (23.1 in) limiting their reach. Above all they are considered as secondary weapons. If by chance they lose it, their greatest advantage in battle is now lost.

3. **Material selection**

In this analysis, three different materials, 4140 alloy steel, CA6NM stainless steel, and 4130 alloy steel, were compared to determine which one would be the best overall choice. To do this we used an FMEA- style ranking system and evaluated each material based on caseability, elongation yield strength, hardness, and corrosion resistance. These properties are important because they affect how the material performs, how easy it is to manufacture and how well it holds up over time.

Starting with 4140 alloy steel, this material performed really well in terms of strength and hardness, receiving the highest scores in those categories. This means it is a strong and durable material that works well in high-stress applications. However, one major downside is that it has poor corrosion resistance, since it is not a stainless steel. It also only has average performance in castability and elongation. Because of these limitations, especially in environments where rust or moisture is a factor, 4140 ended up with a total score of 900.

Next, 4130 alloy steel showed more balanced properties, but overall it was not as strong as 4140. Based on the researched data, it has decent ductility and moderate strength. It scored well in elongation and castability, but its lower hardness and strength reduced its overall performance. Like 4140, it also has low corrosion resistance, which is a big drawback. Because of this, it had the lowest total score of 768, making it the least preferred material.

Finally, CA6NM stainless steel stood out as the best overall option. It had strong performance across all categories without any major weakness. It offers a good balance of strength, hardness, and corrosion resistance, which makes it more versatile than the other two materials. One of its biggest advantages is that it is a stainless steel, so it performs much better in environments where corrosion could be an issue. It also scored the highest in castability, which makes it easier to manufacture more complex parts. Even though it is slightly lower in strength than 4140, it still provides enough strength for most applications. Because of its well-rounded performance. CA6NM received the highest score of 960.

Overall, CA6NM stainless steel was chosen as the best material because it offers the best balance of all the important properties.While 4140 and 4130 are strong their lack of corrosion resistance make them less reliable in many real-world situations. CA6NM, on the other hand, performs well in every category, making it the most practical and dependable choice.

Bronco Knight Analysis of Top 3 Steel Alloy Materials					Ranking	Reasoning
					1	Unacceptable
					2	Less Preferred
#1	**4140**				3	Indifferent
#2	**CA6NM**				4	Preferred
#3	**4130**				5	Most Preferred
Crietia	**Castability**	**Elongation**	**Yield Strength**	**Hardness (45-55) HRC**	**Corrosion Resistant**	**Results**
#1	3	3	5	5	2	900
#2	5	3	4	4	4	960
#3	4	4	4	3	2	768

Figure 3.1: FMEA ranking system of metals

4. Process

Sand casting was the main process used to make the horseman's axe in this project. This method involves pouring molten metal into a mold made from compacted sand. To start, a 3D pattern of the axe was created to match the full design. This pattern was pressed into the sand to form the mold, helping ensure the final shape would come out accurate. A gating system was then added so the molten metal could flow into the mold and air could escape. Once everything was ready, the heated metal was poured in and left to cool and harden. After cooling, the sand mold was broken apart to reveal the axe, and final steps like removing extra material and sharpening the blade were completed.

Historically, most medieval weapons—especially swords—were made using forging because it produced stronger and more reliable metal. However, casting was still used in some cases, especially for simpler tools or parts with more complex shapes. Axes were generally cheaper and easier to produce than swords, which made them common across medieval Europe. They were used by groups like the Vikings and later European armies. Because of their design, axes were effective against armor since they could deliver more concentrated force compared to cutting weapons.

For knights, axes were usually secondary weapons. Cavalry mainly relied on lances or spears during charges, but once in close combat, weapons like axes, war hammers, or picks became more useful. These weapons often included spikes or heavy striking surfaces that could deal better with armored opponents, either by hitting with force or targeting weaker points.

In this project, sand casting directly affected how the axe was designed. Because of limits in material and the casting process, the axe had to be made as a single solid piece instead of using materials like wood and metal together. This meant the team had to be careful with how material was used, keeping the axe thinner overall while adding more thickness where strength was needed.

The design was based on how a cavalry weapon would function, focusing more on swinging and impact rather than long reach. It includes spikes for piercing and a curved blade for striking. Some features, like the blade edge, had to be rounded during casting so the mold would fill properly, and were later sharpened during finishing.

Overall, sand casting was not just the method used to make the axe, but also a major factor in how it was designed. Even though this process is different from how most medieval axes were originally made, it allowed the team to create a functional and realistic design while working within the limits of the project.

5. Design

Due to the limitation for the casting process. The team had to cast the axe as a single solid piece instead of using mixed material for the structural portion of the axe, such as wood for the shaft of the axe. This constraint limits the material usage for all areas as the amount of metal is highly limited. To solve this issue the team designed the axe to be thinner than most historical versions with the thickest portion of the axe at 0.6 in where the widest point on the shaft is 1.6 in. This approach ensures that most of the material is utilized on areas where the loading would be most needed during projected usage of the axe.

Considering the usage of the axe, the axe shall have enough striking force as well as piercing power to puncture metal armor commonly seen on the battlefield in medieval Europe. As the weapon was the side arms for mounted knights, thus the axe should have limited thrusting power to fit the fighting style of the era. The team have decided to design the axe with two spikes that would fit the usage criteria of the weapon. The top spike of the axe is 4 inches long, while the back spike is 3 ¼ inches long, both spikes have the diameter of 0.6in, matching the max thickness of the axe. Due to a portion of the top spike being blocked by the blade of the axe, the practical piercing power and depth of the back spike should exceed that of the top spike.

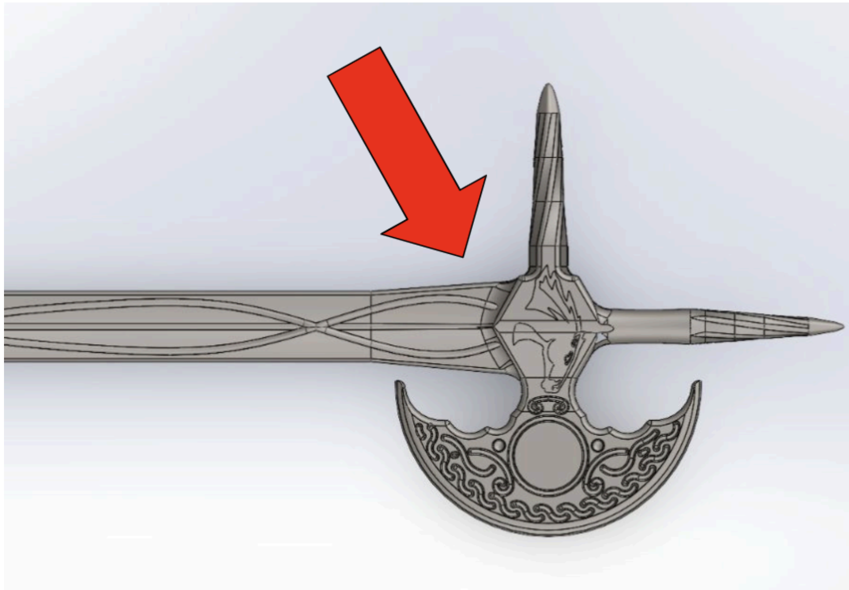

Figure 5.1: Final version of the axe. The red arrow indicates the widening neck. The two spikes can clearly be seen.

The team decided that the blade portion of the axe should be in a similar shape to the waning crescent moon. The edge of the blade is designed to be rounded for castability and sharpened during the post process, this process added additional steps for material removal, but is necessary for the success of the cast. The back of the blade has additional rounding designs for weight reduction as well as aesthetic purpose.

The shaft of the axe is 12 in measured from the top of the handle to the bottom of the axe head. The axe shaft cross section resembles stretched out diamond shape, with the short axis at 0.45 in and long axis at 1.2 in. The grip is designed to be 7 in, which gives the weapon better handling when wearing gloves that are common in medieval Europe. The shape of the handle is a double funnel shape, with the thinnest part at the center of the handle at 0.8in. The funnel shape design would naturally guide the user's hand to the center of the handle. The thin profile of the handle also prevents the axe from rolling when striking a target.

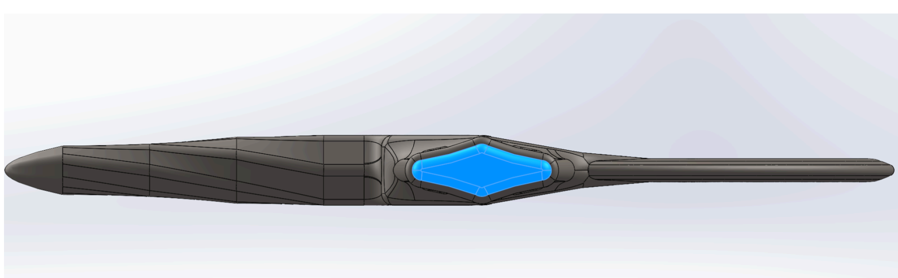

Figure 5.2 Bottom view of the final axe. The light blue part is the grip and shaft shape. The long axis is much longer than short axis, making sure the axe can handle force applied to either blade or back spike direction of the axe.

The axe head design and the direction of the axe were determined to be the most important aspect of the axe, thus the team devoted quite a bit of time in deciding these factors. The first version of the axe already has the traits and shape of the final design. Basic geometry and shaping of the axe were solidified from version 1.0, 1.1, 1.2 and 2.1.

The aesthetic design of the axe centers around the theme of spiral, embracing the idea of “evolution, growth and continuous improvement”. This idea was incorporated starting from version 2.2 onwards. The spiral features were used in both spikes, shaft as well as the face of the axe. Later on, to simplify post processing to save weight, the team decided to drop the spiral design on the shaft in favor of a more streamlined and weight saving design. The hexagon shape on the head of the axe includes two different patterns. The bronco head and a knight helmet, bronco is Cal Poly Pomona’s mascot thus tying the axe to our school, the knight helmet represents us the Bronco Knights.

6. Simulation

The team used SolidWorks for 3D modeling as well as force simulation for this project. For the simulation some of the features will be removed due to added non necessary complexity for the computer. The simulation used 500N as the force applied on the blade portion of the axe, however since the simulation takes the force as absolute and fixed points 100% fixed, it is not a very reliable result, but it shows the areas that might need reinforcement. The team utilized this tool throughout every iteration of the axe to ensure all potential weaknesses are fully covered.

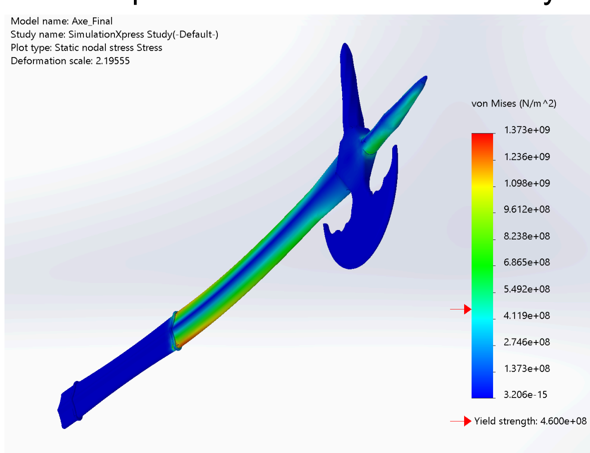

Figure 6.1 Simulation result.

The team used solidcast 9 for casting simulation, the program is able to help the team predict potential issues related to the team's casting model. The gating system is designed based on the feedback from our invaluable industry sponsors at SoundCast.

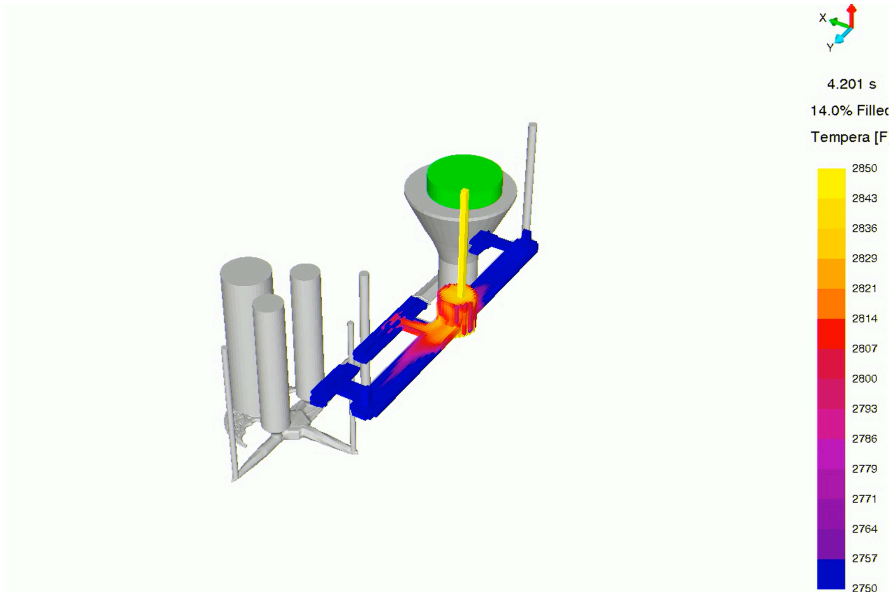

Figure 6.2 Casting simulation

7. Sharpening

The sharpening process was conducted in multiple stages to establish the desired edge and achieve a functional cutting edge. A combination of a bench grinder, belt sander, whetstones, and stropping was used to refine the blade. During the preparation for the sand casting process, the axe was upscaled ~1.5% to account for shrinkage. For the initial removal of the material, a bench grinder was used to establish the primary cutting edge/blade profile and any additional removal required. The target edge angle was between 25~30° as a balance between sharpness and edge durability. Following rough grinding, a belt sander was used to create a more uniform surface for the bevel. This step helped create a relatively flat plane for the bevel in order to facilitate an easier transition for the whetstones. The edge was further refined using whetstones of progressively finer grit sizes (400, 800, and 1600 grit). Throughout this stage, an effort to maintain consistent bevel angle was made by balancing sharpening on both sides of the blade. Finally, a leather strop was used to remove any remaining burr formed during sharpening.

8. Handle

The handle was made by using a layering material onto the axe, consisting of a hemp fiber base and an outer leather wrap. The initial handle geometry was established using hemp fibers as a bulk material to build up the handle profile and create a foundation for the outer leather. In addition, another purpose was to act as padding to reduce vibration from axe use. Adhesion between the hemp fibers and the metal was done using 3M Super 77 spray adhesive. Following the hemp base, a leather wrap was applied to serve as the gripping surface. The leather was first soaked then shaped around the handle and after complete drying, it was adhered to the handle using the same 3M adhesive as before. Once positioned, the leather wrap was also secured by closing the seam using waxed thread. Finally after the adhesive was completely cured and the leather set, the leather was treated using leather conditioner to prevent it from degrading due to moisture/the lack of.

9. Requirements

The requirements given by SFSA calls for a horseman's axe that shall weigh no more than 3.3 lbs and shorter than 31.5 inches. The team had designed the axe to strictly adhere to these restrictions and have designed an axe with a total length of 26 inches and 3.15 lbs. The team's axe is casted in CA6NM stainless steel with minimal post processing, using only sandblast and belt grinder to remove and sharpen excess materials.

10. Acknowledgements

The Cal Poly Bronco Knights consists of students only, however the team would like to put this section here to express our eternal gratitude towards our industry sponsor at SoundCast and Jason Gutierrez for providing continuous technical support as well as providing feedback towards the team's axe design. The team would also like to thank professor Dr. Victor Okhuysen for providing valuable feedback as well as unconditional support that ensures the team was able to complete the project on time. Special thanks to other CPP students that provided their support despite their busy school works, these students included but not limited to: Aprille Joie Le Baquin, Devyn Fidel, Tin Phan and others that helped the team in one way or another.

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