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

Wentworth Institute of Technology: Quit Horsin' Around

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Abstract:

This report presents the development of a horseman's axe optimized for both cutting performance and spike penetration. The design was refined through 13 iterations using CAD modeling and full-scale 3D printed prototypes to evaluate geometry, balance, and ergonomics. The axehead was produced using a sand casting process with a 3D printed mold and cast in CA6NM stainless steel to achieve a balance of strength, toughness, and machinability. The design emphasizes casting-enabled geometry to optimize mass distribution and reduce part complexity. The top spike was intentionally omitted to prioritize blade and rear spike performance within weight constraints. Post-processing included machining, grinding, and sharpening to achieve final geometry and edge performance. The final axe meets all competition requirements and demonstrates strong durability and functional performance under testing conditions.

Introduction:

In this year's challenge, students were tasked with recreating the horseman's axe, a weapon known for its raw force and its multifaceted use cases in battle. While the original axe was forged and included a metal handle, this year's competition included a 3.3-pound weight restriction and a length no longer than 31.5 inches. Teams had to be creative and compromise on what they thought were the weapon's most important features.

Our team decided that the most important features to include in our horseman's axe were the cutting ability of the blade, the penetration of the pike perpendicular to the handle, and the use of a strong, hardened steel capable of weathering even the toughest of obstacles while still staying below the required weight limit. By leveraging 3D printing technology, our team was able to print out multiple variations of the axe to get a feel for its intended use early on, which allowed us to figure out what features we thought It is most important to include this while still creating an authentic weapon that could be used in real battles.

Our design incorporates thin blades, points, and detailed curved geometry that provides strength and support to the main features of the axehead. Our design geometry makes sand casting a viable and preferred method of manufacturing compared to other value-added processes, allowing for a uniform shape that would otherwise be difficult to create. It gave us the opportunity to create a design that minimized post-processing to allow us to focus on other important aspects of the project. The final design was printed and reiterated a dozen times before being cast in CA6NM stainless steel to ensure the final product would turn out exactly as we had designed.

SFSA Competition Importance

The SFSA created the Cast in Steel competition to provide students a medium for creating, learning, and innovating in the casting industry through the use of modern engineering technology and creative casting techniques.

Historical Review:

The horseman's axe historically was used as a mounted weapon during the early to mid-15th century. During these times, many soldiers wore light to medium layers of armor that many medieval weapons had a difficult time penetrating. To combat these issues, the horseman's axe was created. It was originally forged with both the axehead and handle being made of steel. The long range and weight of the weapon allowed for strategic, momentum-based attacks on horseback, giving the wielders an advantage against many ground troops. Despite its weight, it was typically carried on a belt or held below the user, around the chest height of enemies. Its compact design allowed for multiple features that could function depending on the use case while allowing the rider to chain different types of attacks. The curved blade focused on slicing and cutting efficiency. The rear pike could penetrate armor like chest plates and helmets, dealing lethal blows. The top spike allowed for smaller movements in close quarters that worked well against shields. Considering the scenarios this weapon would be used in and applying modern casting and engineering techniques, we decided to redesign our axe with a focus on the deadliest parts. Our design omitted the top spike due to shields being a lot less prevalent throughout the 15th and 16th centuries. By removing this piece, more material can be shifted to the axe head and pike, which we made larger to allow for better slicing and piercing abilities. The introduction of a wooden handle wasn't uncommon, but it allowed for a more lightweight option that provides better control and helps with the shock absorption when striking enemies. Despite the changes we made to our axe, it still incorporates the essence of the horseman's axe and improves upon the features that warriors would have actually used in battle.

Casting & Fabrication Process:

Axe Design

The CAD model for our axe was created in ONSHAPE. This is a program we are very comfortable using and have many years of combined experience in. When first starting our model, we had a rough idea of what our final product would be, but it required great effort to arrive at that point. Our design went through 13 iterations to get the look and shape we were after. 3D printing played a major role in the design process; we were able to bring prototypes of our full axe, including the handle, into the real world before committing the design to steel. These 3D prints were also extremely advantageous for post-processing our casting. Having a reference of the final axe in front of us made grinding the contours and shape of the axe much easier. We also utilized several 3D-printed jigs and templates for the machining of the handle pocket as well as the handle itself. Our axe head was made through the sand-casting process. Using a 3D printed mold made of silica sand and utilizing a direct pouring method, we poured CA6NM directly into an exothermic sleeve with a filter. This casting technique was a limitation imposed on us by our sponsor foundry due to a weight limit of 5 pounds per mold. Despite these challenges, we were able to fill three molds to ensure that even with defects or impurities, we would have a better chance of having at least one acceptable axehead. All three of our casts came out virtually defect-free thanks to extensive use of MAGMA simulations and reiterating our design until we ensured porosity would not be an issue.

Post-production and Finishing:

Axehead

After the axehead had cooled down, it was sent to shakeout, where all of the sand was removed. It was then sent to the cutoff area to have the rigging removed. After cutoff, it was shot blasted to remove any unwanted layers and increase fatigue resistance to reduce cracking. The real post-processing then began. First, the contacts from the riser and gas vents were ground off using an angle grinder. Once removed, the casting still had a rough finish but was not in the shape of the axehead, just with added material thickness. The next step was to grind off the rough-casted surface where the metal interfaced with the sand. This process took a while and was a beneficial way to remove weight from the casting while creating the desired shape for the end product. After achieving a mostly desired axehead shape, we initiated the machining process. The first step was to mill out the pocket that our handle would slip into. We started by using a drill press in the center of the axheads' core to get a through-hole. We slowly stepped up bit sizes until the hole was slightly smaller than the desired pocket size. This allowed us to set up our machine at home and fit the correct end mill without driving it straight into the material. A pocket program was made for the TRAX LPM CNC machine in our school's manufacturing center. It would step down incrementally and trace the geometry of the pocket, taking slightly over an hour to complete. The milling process revealed a small amount of carbide in the CA6NM area. We thought the carbide was a problem, but the endmill cut through it with no real problems. Once the pocket was finally milled, we began the more meticulous post-processing using power tools. The casting weighed about 1200 grams, more than we wanted for the axehead. Working around the weight constraint of 1500 grams, we used an angle grinder with various grit flap discs to remove material while maintaining the original geometry. Different parts of the axe required more precision than others; for the larger flat surfaces, the angle grinder was used. For the curves and crevices, a dremel with a diamond bit allowed for more refined cuts to ensure too much material wasn’t removed. After days of grinding and refining the shape, it was time to start polishing the axehead. Using a range of polishing compounds from 200 to 1500 grit, we were able to bring the rough, grey-looking casting to a shiny, reflection-like finish. After completing the appearance of the axehead, we shifted our attention to sharpening and establishing the desired bevel angle. Using a fixtured plank of wood, we set up two diamond sharpening blocks. Starting with the 325 grit, the initial bevel was made, taking about an hour. We then moved on to the 750-grit diamond block, where the blade became noticeably sharper and the bevel was a lot more noticeable. Finally, the stropping block was placed to polish the blade and create a razor-sharp finish. It was first charged with a stropping compound to enable it to become sharper. A larger angle was used when stropping to create a microbevel to ensure that when the blade makes any sort of cuts, it won't immediately dull and break.

Handle

We selected hickory for our handle material, known for its strength and shock absorption. We purchased a 2x8 section with extra material in case we wanted to go longer or shorter with the handle. Using a table saw, it was ripped into 4 different pieces, which we labeled and graded based on grain orientation and visual defects. Using our worst three pieces, we began practicing cutting out different shapes. Our initial designs involved a lot more curvature and length, but as we began to test them with the axeheads, we found that they felt unbalanced, unnatural, or too long. For our final handle, we decided to go with a straighter design that incorporated a minimal curve on the front-facing side, near the handle. Using stencils and 3D-printed guides, we were able to mark where we wanted to remove material to ensure the best handle geometry. Using a Dremel, a knob was carved out in the bottom of the handle for aesthetic design that also reduces the chance of slipping. The eye of the handle was precisely shaped to allow the axehead to fit snugly. A mixture of 120-grit and 220-grit sandpaper was used along the length of the entire handle to build smoothness and remove any sharp edges. Lastly, two layers of wood stain were applied to the handle to bring out the grain and to add to the sleek aesthetic we were going for.

Assembly

The handle was prepped for assembly by cutting a slot for a wedge at the top of the eye where the two parts interface. Using maple, a wood known for its hardness, we created a wedge to be hammered in to secure the axehead to the handle. The wedge was doused in wood expander before being hammered, and a layer of the same compound was spread around the seams around the handle. The axe was secured in a vice vertically overnight to allow for everything to set. In the morning, the excess handle was cut off and sanded down to be flush with the axehead, leaving us with a fully assembled horseman's axe.

Testing Procedures & Analysis:

Non-Destructive Testing (NDT)

Non-destructive testing (NDT) is a critical component in evaluating the integrity of cast components, particularly for identifying defects such as internal porosity, inclusions, and surface cracks that may compromise performance. While formal NDT methods such as dye penetrant inspection, radiographic testing, or ultrasonic evaluation were not conducted due to time and equipment limitations, several alternative inspection and validation approaches were implemented throughout the manufacturing process.

To reduce the chances of casting defects, three axeheads were made to increase the likelihood of a structurally sound part. During post-processing, extensive material was excavated from the core of the axehead, the most likely location of defects. Despite finding a small pocket of carbide, no other crack, deformations, or porosity was found within the casting.

The axehead also went through functional validation while the blade was being ground and sharpened. It maintained its structural integrity while under standard loading conditions. While these methods do not replace NDT, they provide a level of quality assurance within the scope of the project.

Results & Testing:

Through the use of limited time and resources, we performed various destructive testing with the axe. The blade was tested on various types of wood, including spruce, male, and hickory. The blade had no difficulty cutting through the harder wood types and overall achieved better than expected results. The spike was tested in a similar manner, being used to split wood, impale cans, and destroy fruit. In one test, the spike missed the target and went directly into the concrete floor, reaching a depth of 1 inch and leaving behind absolutely no scratches or marks.

Length	27.5 inches
Weight	1420 grams (1.42kg)

Appendix:

Appendix A - CAD:

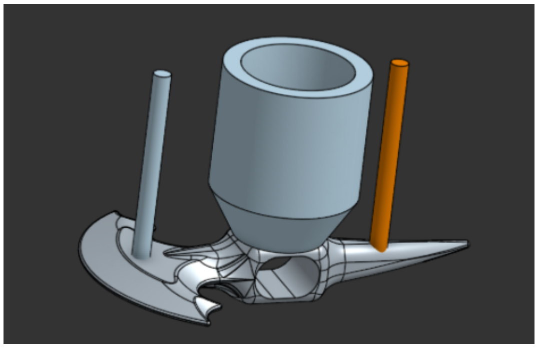

Figure A1

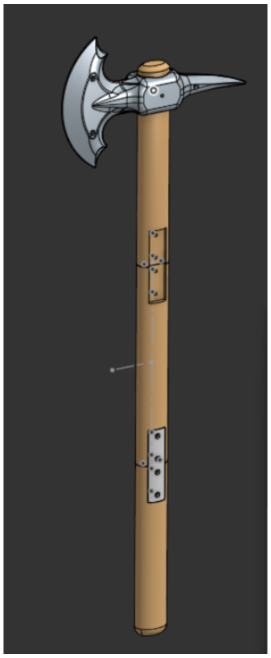

Figure A2

Appendix B - Casting:

Figure B1

Appendix C - Magma Simulations:

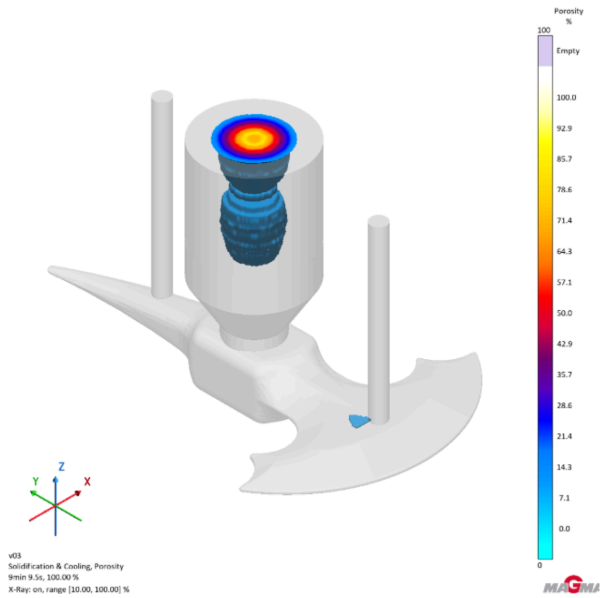

Figure C1

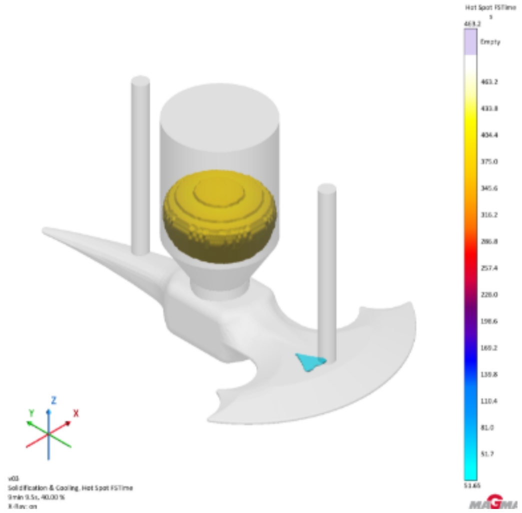

Figure C2

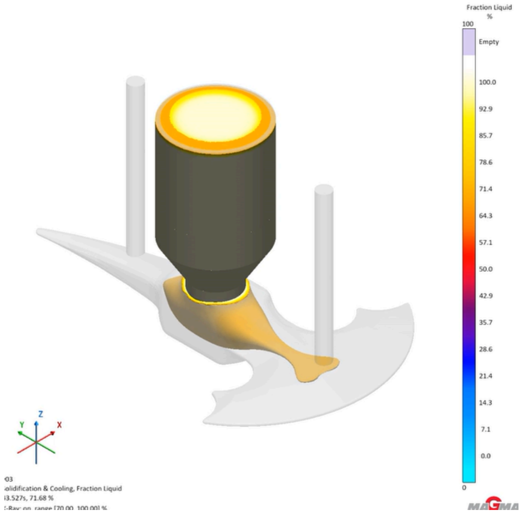

Figure C3

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