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

Georgia Southern University – Three Musketeers + 2

Team Members:

Ryson Haag, Janell Meronvil, William Cooper, Demetri Leontopoulos, Quinn Richardson

Advisor(s) Name:

Mingxi Xu

Foundry Partner:

Carolina Metal Casting

Introduction

The SFSA created this competition to encourage students to learn about making steel products and the casting process while utilizing modern technology. This initiative allowed us to learn techniques and software in a theoretical and practical way. Our team started with no experience at all, none of us had even designed a gating before excluding green sand molds at a few open foundry nights. The development of the axe was a challenge due to the relatively light overall weight, thin sections, and a core. Our axe takes inspiration from original horseman axes which is determined by a medium length, one handed grip, has a head used for blunt force, and a pike for piercing. To mirror older horsemen axes made of metal, we went with a metal handle to pay respects, which presented a challenge due to weight.

Background

While a distinct horseman's axe only appeared in the late 15th century, one-handed axes have been around since over 150BC. The thing that makes horseman axes distinct is that they were made to be a substitute for a lance. The main purpose of these specific axes was that when the lances of cavalry broke, they could still be an effective combatant. The axe itself specialized in fighting armored opponents, since the main part of the axe was to use blunt force, while the pike pierced armor. The length is typically 2 feet and is primarily made to be used while mounted as opposed to a typical 1 handed axe. The main challenges for the axe were to make it light enough to be usable, easily graspable, and effective against targets bearing some resistance.

Material Selection

As much as I would love to say we analyzed alloys to find the best, it would be a lie. For our material, we picked modified 8630 steel, largely due to the successful testing results from previous years' Cast In Steel using this steel. Conveniently, this modified 8630 steel was deemed quite useful for our purposes and was likely one of the best choices. Belonging to the 86XX series, it contains nickel, molybdenum, and chromium, which provided us with a steel that grants us great mechanical strength, hardness, and the capacity for handling dynamic loads. This steel is also used in ground engaging applications due to these properties as well, making it reliable at standing up to mechanical stress because of its balance of ductility and toughness, which allows it to withstand impacts without fracturing and is greatly improved by heat treatment.

Computer Aided Design

One of the advantages presented to us with using modern technology was the use of Computer Aided Design (CAD) software. Rather than having to hand sketch each design, we could instead use CAD software to model our axe head and its handle, which greatly helped us to reach our final design. Both designs were simple, considering the requirements were only the total length and weight. With SolidWorks, however, we could set the material density and get an accurate picture of the size of our axe with volume instead of having to estimate the weight with each design. The main thing we had to ensure was that our parting line was even and that we accounted for the shrinkage applied by patternmakers' law (about .02 inches for our 1-inch casting). For clarity, the half-riser seen in Figure 1 was so that we could slot a breaker core on.

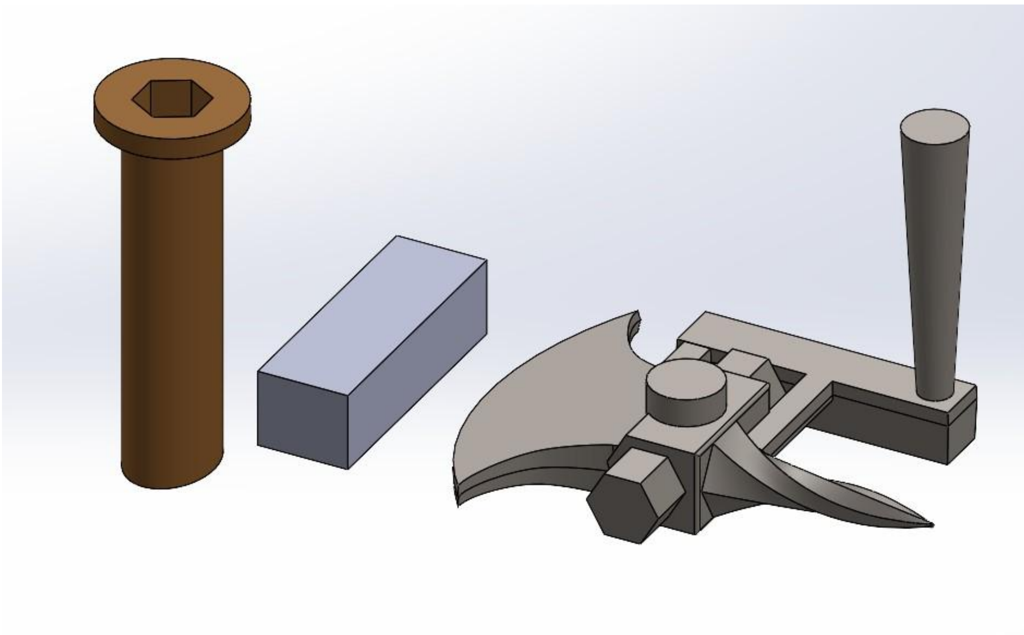

Figure 1. SolidWorks models of the horseman axe and handle

Casting Simulation

One of the most useful things that the Cast in Steel competition taught us was how to perform casting simulations. We utilized the MAGMASOFT software and started with our design by using primarily theoretical math, which revealed where we went wrong with our initial design. However, it taught us what to do better. Eventually, after a few dozens of simulations and trial and error, we found different improvements that would have a massive impact on our castings. The simulation told us where we had potential for porosity (Figure 2), and the cooling curve, so we knew where to look and impacted us on the risers we used and saved us a lot of yield percent we otherwise would have wasted for no real gain.

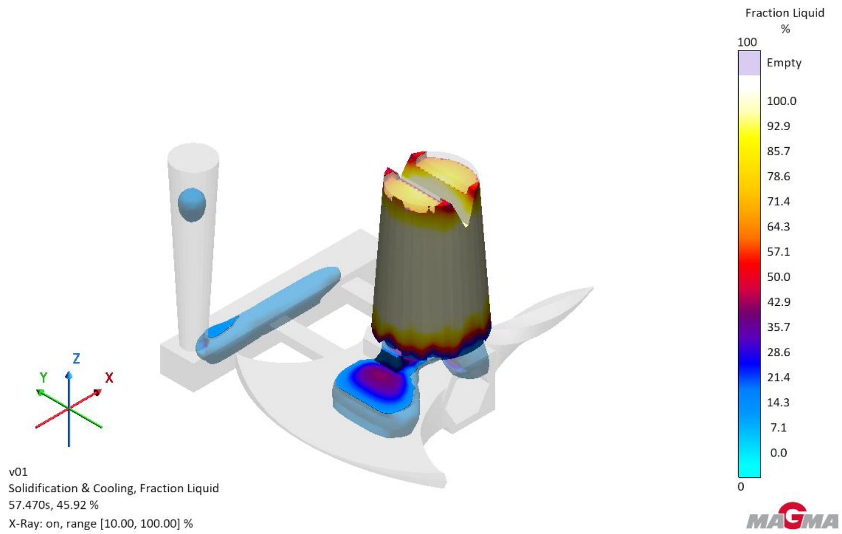

Figure 2. MAGMASOFT Simulation showing the last portion of liquid in the axe

Model Printing

The third improvement in modern casting is 3D printing, which was significantly cheaper and faster than trying to make our model out of wood. We used a printer with PLA (Polylactic Acid) for the main axe head and the core box, as seen in Figure 3. This allowed us to have a prototype in our hands within a day, rather than the time-consuming and costly process of trying to whittle it or worse, machine a mold. The printed model was then coated with Zip Slip and put into a flask to be able to make our sand mold. To investment cast the brass handle grip, we used low-carbon filaments, PolyCast, rather than performing the traditional method of making a die and filling it with wax. We used the filament to make our pattern, then burned and washed it out to get a shell for the casting, as we did with our handle.

Figure 3. 3D printed models with core boxes

Molding

Molding was where we made most of our mistakes, but in the end, it showed to be a learning experience and improved our design before the final casting. We tried to avoid getting help, wanting to learn while doing it. Our first model made it halfway out of our lab before we got stopped and asked by a graduate student, “Did you calculate the riser before or after gating?” Our first mistake before we started was not asking more questions before going on to our final products. Our initial few designs, even though MAGMASOFT did not find it, had us pour with too much velocity, which led to small porosity from air entrapment on the bottom. We later fixed this by redoing our gating math more tightly and through optimization. With our next and final design, we went with an exothermic riser with a breaker core, which allowed us to put a longer spike and a tighter bevel without porosity. For the handle we cast it via investment with another model to be able to have a better tree, and a better yield for the brass.

Figure 4. Investment Cast Handle Mold

Heat Treatment

We took it to 926°C for 1 hour, which allowed the carbides to break down into austenite. Where upon we then quenched it in oil to a holdable temperature as we transferred it to a different furnace set at 400°F for 1 hour. The second heat treatment being an hour is an uncommon practice, however, in one of the previous Georgia Southern University graduate's thesis papers, found at 400F removes the chance of cementite that forms at 482°F or more. Additionally, our axe's thickest part is only .6 of an inch which obeys the two hour per inch rule when heat treating steels, to prevent internal cracking when quenching.

Final Assembly

For the final assembly, as seen in Figure 5, our axe was put together by placing epoxy in the joints and leaving it to harden to attach the brass handle and our axe head to the aluminum shaft. We coated the dowel rod in epoxy before inserting it with the goal of obtaining the most surface area attached to the rod as well. After it was hardened, we further secured the axe's head and handle to the shaft by inserting two aluminum pins through both parts, before once again sealing them in with epoxy. This allowed us to have 2 safety factors and reduce the risk of injury since our highest chance of failure was for the head or the handle being broken off.

Figure 5: The Final Axe on a transparent background.

Non-Destructive Testing

For Non-Destructive Testing (NDT), the three easiest forms of testing you can do are ultrasonic testing, hardness testing, and dye testing. For dye testing, we opted not to use, since we had an unfortunate amount of notable pinhole porosity on the surface even after our finishing, with this porosity dye testing would not have indicated. After consulting the Casting Defect

Handbook, we believe the pinhole porosity was from the velocity entering the casting. For the ultrasonic porosity testing, we did not have access to one that can do internal pictures; however, we did use a gauge tester (one used in testing the thickness of pipes), which told us how thick the metal is. When measuring (Figure 6), if the gauge did not read below the thickness of the metal, then we knew we did not have porosity or a hole in our axe. The main flaw in this method of testing was that it only had a tolerance of 1mm, so if we had a hole smaller than that, it would remain undetected. The third test we did was to verify the exterior hardness of the axe head to make sure the heat treatment was successful by using a Rockwell tester, a hardness of HRC 52 indicated a successful harden of our axe hand.

Figure 6: Using a Gauge Tester to verify Axe thickness in mm.

Destructive Testing

While NDT is useful, destructive testing proves more effective when testing durability. Unlike wood handles, our aluminum design would not fracture, but bend if it experienced failure, adding yet another factor for the safety of our axe. With the bending properties of aluminum, our handle would not start to bend until 200lb is applied on the axe, which would not be possible with one hand, even on horseback, as any person would lose grip with that much force. This does mean, however, that more responsibility falls on the security of our attachment of the head to the handle. Between each destructive test, we verified the integrity of the resin to make sure no cracks appeared and ensure the pins did not move. The final step was to put our axe to use by repeatedly hitting it into ice, barrels, wood, fruits, rope, and metal. This ensured that we knew the final product would not chip, so long as the other factors relatively the same, like the hypothetical porosity inside of the axe, if any. This ensured that we knew the final product would not chip, so long as the other factors remain relatively the same, like the hypothetical porosity inside of the axe, if any.

Final Specifications

Our axe head is modified 8630 steel, the handle is an aluminum stock with a poplar dowel rod, and the handle is C69300 silica-brass. Our axe comes in just shy of the weight limit of 3.3lb (1.5kg), with our axe being 3.29lbs or 1.49kg. The final length comes to 27", which is shy of the 31.5" mainly because we had to shorten it when testing the feel of the axe to be best wielded. As its original length left the overall feel of the axe unwieldy from all the weight being concentrated so far away from where you would hold the axe.

Thank you, Dr. Xu, for all your advice and assistance throughout the construction of this axe.