SFSA Cast In Steel 2026

Robert the Bruce's Horseman's Axe

Technical Report for the Casting Submission for:

Arkansas State University

RED WOLF STEEL

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.The 2026 Cast in Steel competition challenges colleges to design, cast, and test their own version of a horseman's axe. The competition was started by SFSA to introduce students to the benefits of casting while giving them hands on experience with new technologies. It also provides a way for those competing to build strong connections with industry partners, which could last long in their careers. Arkansas State University, along with industry partner Southern Cast Products, have sponsored a group of ambitious students to rise to this challenge.

The team Red Wolf Steel includes students who are pursuing a degree in both Mechanical Engineering and Engineering Technology, which provided a strong skill base to start from. The group was structured where each student would do every part of the project independently, then share their results during a meeting. All decisions were made in this way, meaning a discussion was had before every step of design was finalized, and we did not proceed until everyone was on the same page. A timeline was created during our first meeting to keep our group focused and organized, which can be seen in Appendix 1A.

Material Selection

Our industry partner Southern Cast Products was consulted to determine the possible casting alloys we could use. It was decided that the two best options were 4140 and 5160 spring steel. After each member of the group did independent research, it was evenly split as to which we should use. The benefits of 4140 were the ease of machinability and high toughness. With carbon content of around 40% it would be hard enough to keep an edge but ductile enough to be easily machined and sharpened. Despite these benefits, the higher carbon content of 5160 steel, being around 60%, made us choose it as our material. It is the same alloy that was used during the previous project, so the veteran members felt comfortable using it again. Southern Cast was consulted again, and they approved our choice.

For the shaft and grip, we ultimately chose hickory, but experimented with oak to get our shapes and weights to the correct metrics. Initially we considered bronze adornments, or even a counterweight, but a counterweight isn't needed in mounted combat as much, and our weight constraint is relatively small this year. Our desired material would have been ash, as it's likely the material that was used in Scotland at the time, but it wasn't as accessible.

For the grip itself, we considered the most authentic-seeming choice; leather, but found that the leather material didn't seem as comfortable as just contouring the wood itself. We considered using spray-enamels such as spray-paints with texturization. However, the team felt this wasn't historically authentic, and might not look good after sealing the wood.

The final shaft was hickory, singed on the exterior to create contrast and seal the exterior layer of wood, then layered twice with linseed oil. The grip included no extra materials and was simple shaped by hand to create an ergnomic grip for a left or right hand grip. Though a few prototypes included engraved textures, This was not elected for the final design.

The final choices were 5160 spring steel for the axe head, and hickory wood for the shaft and grip, treated with linseed oil, and a hickory wedge. No leather, no fancy adornments, just wood and steel without any added weight, need for expertise, or complications. The final alloying for our 5160 steel can be seen on Appendix 1D

Historic Research

Robert the Bruce's Axe at the Battle of Bannockburn (1314)

Robert the Bruce, known as the Father of (Scottish) Freedom after this battle, was taken by surprised, and under-armored by Henry De Bohun, an Anglo-Norman knight. Robert noticed him reading his lance and charging him, and elected confidently to ride into him with his battle-axe. He stood in his stirrups and manuevered around the lance's blow, and struck his axe directly into Henry's helmet.

Fatal Blow was delivered by the blade of the axe, as was noted in the later-historic documentation; "That ner the heid till the harnys clave" was used to describe the delivery of the injury. It would translate, in context, into "It was driven far enough into Henry's skull that it was cleaved"

The axe was supposedly damaged and it was disposed of after in battle, according to Scottish writer John Barber.

The Vita Edwardi Secundi, a more historically accurate depiction, does not depict this scenario, and does not include a broken axe, but Henry's horse was slain by spears as he crossed a small creek and attempted to file ranks, after passing through a dangerously a narrow corridor with a large troop movement in tow. Many depictions show the axe with and without a pike, and unfortunately there is no way to know which one is accurate. His real axe was not preserved or kept after the battle. It's often depicted with a pike, but this may not have been the case.

Incorporating History Into Our Design

We originally wanted our axe to follow the artistic rendition of Robert the Bruce's horseman's axe, as depicted in Appendix 2A. It is unique to other axes of its type in that it has more of a hatchet design than the traditional axe, which we wanted to incorporate in our design. Likely because it is an artistic interpretation, it lacks both the pike at the top and spike at the back of the head. A horseback rider would frequently use the spike on the back of his axe to pierce the helmet of any unfortunate infantry they passed, so we thought it necessary to include the spike in our design. It was also decided that a belt loop was not necessary, since it would be yet another breaking point and a horse rider could easily loop the axe through a leather strap attached to their belt instead.

Remnants of our original hatchet design can be seen in our final design, such as the relatively shorter blade and wide mid-section, where it overlaps the handle. Everything else on this final design was inspired by medieval gothic armor, as seen in Appendix 2B. It was important that we cast an interesting shape of our axe, since we wanted to cast something that would stand out compared to forging techniques available at the time. The combination of curves and sharp edges present on these beautiful mid to late 15th century pieces of armor provided the perfect inspiration for our more ambitious sand-cast design.

Appendix 2B shows the armor of Sir James Scudamore, who was a knight under Queen Elizbeth I of England. This armor was designed in pieces, so certain parts would be switched depending on if the user was in a cavalry, infantry, or tournament setting. It is entirely possible that Sir James Scudamore would have used a horseman's axe in this armor. Appendix 2C shows the armor of Prince Elector Christian I of Saxony. This armor was made for a competition where two knights would engage in hand-to-hand combat over a fence using swords or pikes. It is unlikely a horseman's axe would be used for these competitions, since no horses were involved, and a basic pike would work just as well.

Design

Each group member was tasked with doing research and designing an axe to be shared with the other members. Each design was analyzed, and the pros and cons were taken account of, then used to improve the subsequent designs. It was important that all members were happy with each iteration of the design; we did not want the design to be the work of a sole individual, but a group-process. Out of the five initial designs submitted, two were chosen to be the base for iterations. Appendix 1B shows our initial hatchet design. The hatchet shape was universally liked, but the spike at the end caused worry. It was too thin to be trusted with piercing anything, so that was the first of many fixed that needed to be made.

An important discussion was had regarding the pike that is present on the top of most historically accurate Horseman's axes. It is not present on all of them, but some team members liked the design and wanted it to be included. There were ideas of casting it with the head or casting it as a separate piece from the head where it would act as a sleeve, keeping the head pinned into the shaft of the handle. This concept can be seen in Appendix 3A . It was decided that any piece sticking off the top of the axe was inherently weak. It would only take a bad swing for the pike to hit the surface instead of the blade, and it was very possible that it would break off. Because of this risk analysis, the pike was removed from future design considerations.

With our initial designs shared, a new head was made from scratch to represent what was important to each team member. It kept the hatchet design while increasing the width of the spike to acceptable proportions. To get a better feel for the scale of this design it was 3D printed. Everyone agreed that the design was good, but it was too small to do any damage. It was decided that the next design would have to have a substantially larger blade and more realistic proportions.

We determined the material to be 5160 Carbon steel before doing any designs so that we could have an accurate weight. Unfortunately, using the realistic dimensions pushed the weight of the head past what we were comfortable with, so the scale of everything had to be reduced. The sides of the axe were trimmed down, and more indentions were added into the spike, allowing the extra weight to be maneuvered into the blade. Everyone was happy with this design, so we sent it to Southern Cast for comments.

Up until this point, it was believed that we would be making sand mold for our design. A member of our group had an industry visit at Southern Cast Products where he learned the limitations of sand casting, such as necessity to avoid sharp edges and that a quarter inch was as thin as a casting could be without cracking. All designs that were made were based on the idea of casting as a mostly full shape, with little machining left at the end, so these limitations ended up being an integral part of our designs. Our industry contact met with us after seeing the model and said we would be allowed to use the 3D printed method of casting instead, which reduced the need for strict limitations. He encouraged us to make a less conservative design and reassured us that anything we came up with would be feasible. This revelation led to two completely new branching designs being developed.

One design used the measurements of the previous axe but added some "weight saving measures" which includes holes going all the way through the side of the blade making an almost spider-web shape. The rear facing spike adapted an almost cage like appearance, we used this idea of a cage to explore some interesting options. We were inspired by certain railroad spike art to try and put a marble into the back end of the axe. While not historically accurate it provides a look into the advantages that casting gives us. Adding a hole to go from the handle hole into the empty pike allows us to place a marble of appropriate size and insert our handle, effectively locking in the marble with no obvious way for it to escape. A cross section of this axe is provided in Appendix 3F.

Casting Mold Design

To create the model for the additive manufacturing methods used in sand-casting, the team needed to take their original models, and convert them into molds, or negatives of the original shape. Initially the team sent a design to Southern Cast Products and recieved a mold design in return, but also instructions on how to create it for design B, and some recommendations on changes to the design that might benefit it's casting.

Design A was cast first, during the period of time that the SFSA film crew came to campus, so we were able to take it and work on it a little for show, but the film crew had showed up precisely when the annealing process was being done, so one axe head didn't get annealed, or heat-treated. We felt it was better to at least have a visible representation, and something to simulate the work we would be doing next week on for the film crew.

Design B was cast 2 weeks later, and other than one axe head having a crack in it, they turned out well. These would be overweight at the time of removal from the risers, but ultimately be reduced substantially by machining. Both designs included a core which would need to be removed before the shaft could be fit throught he head and wedged into place. This core would also add a deceptive amount of weight to them, and left us a bit worried until it's removal, on both units.

The pin holes were removed from both designs due to improper placement, and a decision to entirely avoid the use of pins, and simple use a wedge, that may possible have tensor pins inside of it. Ultimately we did not use tensor pins, but simply a hickory wedge. Both designs will be used with a VX2000 sand-casting machine will create a layered mold of harden sand for each axe head design.

Shaft Design

We initially chose to only allot for a certain amount of mass for a shaft, and solely focus on meeting deadlines for casting steel with our sponsor, so the shaft had to meet strict constraints for mass, and length. The team would have preferred to make a much longer shaft suitable for mounted combat, but within the weight limit, the only designs the team felt were more of an axe, than a tool, were the ones that limited our length. The initial premise would have been to consider it to be a tool for mount-to-mount combat, that's similar in length to halbreds, and can be used to hook armor, or use as a pike, but this weapon seemed more identifiable in the modern age as the halbred, or some sort of polearm. The team chose to use the more historically glorified design of an axe, that is optionally for a mounted "horseman."

The respective axe head designs put the weight limit for either shaft, initially at under a pound, and our simulations for wood apparently were somewhat inaccurate, or the wood we had at our disposal was possibly drier or less well-treated. The shift from our craft wood oak material to the hickory material was stark in terms of quality, and to an extent left much of experimentation with oak totally unfruitful. The Adirondack-style shafts were creating weight-limit breaches, so the axes were ground down a bit more, and the bevels of the wood were made more dramatically subtractic until an good balance betweein arching shapes, and the flow of the wood grain was achieved.

We had much grander plans for creating ornate designs, but reliquinshing the design of the shaft to a later date, and a very strict weight limit made this less possible than desired. Wood burning methods were suggested, but rejected, as the final product already had a quality not worth risking disturbing. The team's final shaft design is a very comfortable, and useful design comprised of many concepts considered previously.

Casting/Cutting

With our designs finalized and approved by Southern Cast, it was time to create a casting model for our axes. To reduce the chance of shrinkage, two large risers were placed on either side of the axe. As the molten steel cools in the mold it will inevitably shrink, so it is important that the risers always have enough material to fill the gaps as they are made. Because of this, the risers needed to be designed so they are the last to cool. Novaflow was used to perform phase and shrinkage simulations, which can be seen in Appendix 4Eand 4F.

With our simulations looking good, a 3-D Sand mold was created by drawing two boxes around the original model, with the bottom being the drag and the top the cope. A core was inserted into the middle of the model where the hole for the handle is, this was done to keep the sand in the middle from getting too hot and deforming. Three pegs were inserted to insure alignment for casting. Our final sand mold design can be seen in Appendix 4G.

This design STL file will be converted into proprietary code for the VX2000 Sand-casting unit used at Southern Cast Products, then that code will be used to create a sand-cast mold for the steel to be cast within. The molds will have a cope and drag that are placed together in a mirrored configuration, like the image shown of design A in appendix 5D and 5E.

The VX2000 uses alumina-bonded ceramic sand (carbo-ceramic sand) and acidic binding elements to create a 3D model, which is sealed with thermal pastes after casting. It's printing dimensions are 1000 mm X 1000 mm X 2000 mm (hence why it's called VX200) that's approximately 80 in X 40 in X 40 in, making our axe heads much faster prints than the sword was during the previous year. This is much of the reason why we had the ability to test more product units this year than last year, and also the reason we had the liberty to test two models.

Machining

After our axes were cast, they needed to be removed from the risers. This was done by cutting them off then grinding down the raised spot they left. Since the dimensions of the cast model were significantly larger than our desired final dimensions, the heads needed to be grinded down substantially to reach our weight limit. Thanks to our annealing process, this was not a problem. We did have an issue with the core, however, since a steel post was placed in the middle to resist shrinkage on the sides. The hole was not wide enough to fit a Sawzall, so a hacksaw had to be used instead. Even after annealing it took hours of elbow grease to get just one post out of an axe, not including the time spent filing down the remaining jagged metal. Each team member pitched in after a tedious week all the posts were removed, and the axes grinded into their final shape.

The initial test runs of the shaft, for prototyping, were created using oak wood, as it has a similar weight, and a the team wanted to get a feel for which grip felt best to hold and use. The wood was delivered in 2x4's and then cut down with a variety of saws into 3 primary design shapes, then the grips were experimented with from there as best as possible. The first few cuts of wood came out underwhelming both due to refining our technique, and due to using the lowest qualities of wood first. A few cuts of the wood had burls or gnarls within them that made them tantamount to waste, aside from practicing getting the form right.

The grip was given a few ergonomic, pistol-grip-like iterations, but ultimately the axe grip and shaft moved toward that of a felling-axe, but with less curvature, but a more desirable balance and length.

Heat Treatment/Quenching

During last year's competition our team had a substantial amount of difficulty machining down the sword into an even sharp shape. Because of this, an annealing process was decided early on to mitigate most of the machining troubles. When a metal is cast, it has a complex and jagged microstructure; this makes it hard and brittle. Annealing is heating the steel into the Austenite region and holding it there until the microstructure can realign itself. It is then cooled slowly so the carbon can in the microstructure can be rearranged into a more ductile and uniform position. Based on AISI standards for 5160, a full anneal was performed at 1,450-1,525F with a soak time of 1.5 to 2 hours. It was then placed in a heater, and the temperature slowly decreased at 40F per hour until it reached 1,000F, where it was finally able to air cool into a ferrite and cementite phase as shown in Appendix 6A.

After machining was completed, hardness needed to be returned to the steel which was accomplished by quenching. It was heated to 1,600F, which is higher than the annealing temp but still in the Austenite phase because we wanted the microstructure to be disorganized. When the steel is placed in oil the disorganized nature of the steel is maintained, since there is not enough time for it to become uniform. The chaotic structure is what makes steel hard, while a organized structure causes a steel to be ductile and soft. This can be seen in Appendix 6B, where the temperature of the steel needs to be in the high Austenite area, but reduced drastically into the hard Martensite area, before hitting the nose of the Ferrite section. The temperature needs to drop roughly 1,000F in under 10 seconds to achieve this result.

Unfortunately one of the hole designs cracked under quenching. It is believed that the blade's edge was thinner than that of the others, causing it to warp when it was quickly cooled. Since there was not enough material surrounding the connecting portions, the blade snapped apart instead. We were lucky that this only happened to one of the blades, but it is why we made the strategic choice to make a conservative design as well. The crack was welded then grinded back into shape, but we marked it so it would not get submitted in case it was weaker.

After this process of hardening, an amount of ductility and toughness is still required for the axe to perform at its best without breaking. This is done by tempering the axe, which involves heating the steel well below the Austenite temp and keeping it there for a couple hours. It is then air cooled, where the stressed carbon atoms have time to realign themselves into cementite points in the ferrite structure.

The sought-after hardness was between 55-58 HRC. After consulting heat treatment literature, it was found that the axe heads needed one hour per inch of section thickness at 450F for the tempering process. Using the dimensions of the CAD models, the axe heads were heated to 450F for 78mins, then left out to air cool. To ensure all of the internal stresses were removed, the axe heads were tempered twice. Since both designs were to be tempered, the team simply used the model with the largest section thickness to determine the final heat treatment times, as none of the processes would negatively affect the performance of the axe heads by being over-treated.

The result will be an axe that is more difficult to sharpen or subtract material from than prior to hardening, but it will be in it's ideal form for use as a weapon in this sturdier form and have better blade retention, while still being easily sharpened. Assuming nothing adverse has happened, our axe should be a marvel of both the natural world and human engineering that we hope would be more than sufficient for Robert the Bruce's expectations as the Father of Scottish Freedom.

Grip

With our axe heads treated, it was time to dedicate ourselves to crafting a worthy handle. We considered using either ash or hickory as the material, where ash is less hard and easier to shape than hickory. We determined that only the hardest wood would do so we contacted a local lumbermill and obtained a strong piece of hickory. After multiple practice trials on soft pine wood, we were ready to begin working on the more difficult wood. Unfortunately, we did not predict just how tough and heavy the hickory handle would be. The oak was shaped with a band saw, but it could not cut the hickory in the same way, so we had to resort to chiseling out the rough shape then sanding it down to the final dimensions. This took substantially longer than the oak, which put us behind schedule. After each oak handle, we weighed the axe to make sure it was well below the weight. We did not anticipate just how much heavier the hickory would be, the same design put our axe more than a pound over the weight limit. Because of this we had to compromise, making the handle shorter and removing some of the decorative flair, which can be seen in Appendix 9C where we submitted the smallest iteration.

Some of the earlier oak shafts weren't of a very high quality, and were mostly done to gain experience in shaping wood. This caused one of the earlier tests in wedging an axe head to fail due to material quality being too low to be suitable. Luckily no one was injured when this axe failed critically, causing the axe head to break off and traject. The break was due to the wood having a gnarled, diseased portion, as show in Appendix 7A. Again, this was just to test out the methods without wasting our good material, so no unexpected loss was incurred.

Early designs considered the notion of a pistol-grip like grip, as seen in Appendix 7B-D, but ultimately we selected the forward-curved Adirondack-style shafts and grips seen in Appendix 7E-F. This design was studier, and counter-balanced the weight of the axe-head much better. Any reductions in material to create a grip reduce the internal stability of the wood, so we chose to simply rely on the texture of the wood and linseed oil sealant. The option of using enamels to seal the wood and create a grip seemed too anacronistic for the era, as this was definitely not something readily available, and was mostly a result of our very limited weight-limit, not actual preference. Though, in terms of utility, it was surprisingly effective. The option pictured was simply a metallic-paint enamel for multi-surfaces by Krylon, but anti-slip industrial liner and stone-texture enamels were surprisingly durable, flexiable, and absorbant of impact. They were also mostly, other than the metallic texture, terrifically ugly-looking and probably would have angered a king.

There was a brief election to use leather straps that would have been cut out in patterns by our laser etcher, but this also required facets, or adhesive, and in itself, would be enough weight to require more grinding again on the steel components, which the team neither had the time, nor desire for doing when the result would be very unreliable and likely waste materials. Though it would have been most authentic to the era, the later-consideration for the shaft, and under-estimate for each components weight-distribution for the overall assembly, this made the construction of the shaft and grip a bit rushed.

The final result feels exceptional when held, and for a first product result, we feel very proud of the result. The overall balance of the axe improved by simply extending the pommel and creating a forward-curve, but ultimately a weapon for this purpose required at least the amount of mass that we included, and for the king to expect any axe intended for mounted combat to weigh under 4 lbs seems like the challenging aspect, and we're confident we've met the goal at the best of ability, and within the constraints of the competition, with our final shaft designs.

Assembly

The team had eliminated quite a few details that could add to the assembly time and expertise, such as a pike, support/safety pinning, enamel coatings, and any need for extra material asside from those used to support or protect the wood of the shaft and wedge, and the steel.

The team still intended to test the quality of two axe designs chosen to be cast, with a variety of configurations of shafts. The configurations were only photographically documented, as they were completed and tested as our college's Spring Break began, which forces students out of the dorms, and often out of town, for a week. The final axe that was sent to SFSA was completed by team member Sam Morris and mailed, despite the process and components having been completed and decided upon prior. This was done simply because the team would also be losing access to facilities at the college as well during this period. So the team, coordinated the week prior to adjust for this during the last meeting before our break.

The group had already had many discussions about the best way to finish the axe head. We debated using linseed oil, bee wax, or a bluing compound to give it a strong outer coating. The look of the bluing is what won us over; the deep black was perfect for the shape of the head, and it would soak into the steel, providing more than just a surface coating. After being polished with a fine grit grinder disk, the bluing compound was applied twice to the steel, followed by a surface protectant coating. This gave the head a deep black color and a shiny finish as shown in appendix 9A.

The handle was charred with a torch which provided the surface of the wood with a moisture resistant layer, while also raising the grain improving the grip. Different stain types were used but we found that Danish Oil soaked in the best and had the most aesthetic finish. We decided to use the walnut color because it complemented the dark head.

Initially the heads were being set off of the initial axis used to plane the wood, but once the team began to adjust the curvature of the head to match the needed forward-curve for the Adirondack-style shafts, the only thing left to do was wedge the wood. Though the earliest attempt at this had failed critically, this was solely due to the individual cut of wood used in that instance. All later assemblies were fully functional with their wedges in-place and had no noticable flaws in their materials.

The team chose to not include a pin through the center, as it would damage the integrity of the wood more so than a wedge that would diffuse vibrations from strikes on metal surfaces. The entire process has been a dance with balancing the weight alloted to the axe head, and how much weight can be contributed to the strengthing of the shaft for delivering striking blows.

The wood was treated with linseed oil in 2 separate 24 hour sessions to create a seal on the wood for the shaft and wedge, and give it's a stickier-to-the-touch texture. Walnut-colored stains were applied once before this to the wedges and shafts, then the shaft and the head were affixed with a mallet by the wedge afterward.

This simpler process was not only easier for us to achieve with no experience as blacksmiths, but also would allow for a more controlled manufacturing process for future models to be created. It also reduces the number of things that can go wrong with our limited time to focus on this task, and the simplicistic approach appears to have paid off, as this year's result is outstandingly more complete, and purposefully planned than last year's submission was. There's no denying the fact that a significant improvement was achieved.

Field Tests

One of the eight axeheads, a Design A head, was not fit for testing, as it was removed from the normal round of annealing and treating to be presented. Another Design B axe was slightly cracked, and was given a weldment for repair. This axe, ultimately became the first "field test" axe, though it was only photographically recorded.

Since the main purpose of the axe was to pierce steel, performance testing was done on a piece of sheet metal. The spike pierced the metal with no issue, but after repeated impact the blade tip became dented. We continued sharpening the blade with the polishing puck until we got the angle right. We believe the angle was too narrow at first, causing the blade to fold over on impact. With a slightly thicker angle, it was able to take more swings with little damage. We also performed testing on a wood block to determine the sharpness retention of the blade and chopping power. The blade cut chunks out of the wood easily and left very little damage after repeated hits. It also made quick work of some logs that were turned into firewood. Hardness testing was discussed but unfortunately, we ran out of time to arrange and perform the test with Southern Cast and we have not received on for the school yet.

The initial first tries at shafts and grips had all been substantially narrower, and unreliable, the later designs used for the Design B axe head were substantially thicker and made of better quality wood, with one shaft using the Design A head. The team chose to field affix heads to and test only the adirondack-style shafts and grips and there's no actual recorded data of these NDT tests to present.

We don't seem to have our grain microscopy, or alloying tables this year either, but the axes have, so far, proven durable enough for their intended purpose, and the team is eager to see them put to the test, whatever it may be. There is also no actual footage or recorded measurements for our field testing to present.

Final Thoughts

The largest challenge we faced was time commitments and the weight limit. Despite our best efforts to stay ahead of schedule, something always seemed to push us back. The weather and scheduling conflicts were the main reasons why we could not do everything we wanted, including more extensive testing. The weight limit was another difficult challenge for us to overcome, but it resulted in us performing the most advanced and risky cast we could have done. If it was not for the weight limit, we likely would never have considered making an axe with holes in it due to the constraints of casting, but through conversations with Southern Cast and many tweaks we were able to get it finished. Coordinating as a team, and having a issue-ready schedule in place helped us understand how to execute a project, though our monitoring and recording is a bit lacking. Each year, we know we will learn something, and that we will be able to contribute that something to next years team's experience in the form of advice and wisdom. Every year that the team participates, is a year of not only learning the process of making steel tools, but the process of finding the creative edge to help pass a brighter torch to next year's team with what we learn from our experience.

We have learned such a great deal from this project, from building contacts and gleaning wisdom from our industry sponsor Southern Cast to researching and executing the casting process. Our understanding of what can be cast has grown much wider after challenging ourselves to make the best axe we could. Everyone on team Red Wolf Steel is so proud to have been a part of the process and would like to thank SFSA for the opportunity to create something amazing, and the memories that came with it.

Red Wolf Steel's Horseman's Axe
Overall Weight: 3.031 lbs (1.379 kg)
Overall Length: 18 inches (457.2 mm)
Axe-head width: 8.5 inches (219.7 mm)
Axe-head depth: 1.5 inches (38.1 mm)

Methods: Design with SolidWorks and OnShape (OnShape for final)
Cast in Alumina-bonded ceramic sand molds
Cut from mold and annealed (except the exhibit unit)
Grinded to requirements
Heat-treated for HR 55-58 (untested)
Surface polished and blued, then edges sharpened
Shafts cut, sanded, and stained/sealed
Assembled with Hickory Adirondack-style axe shaft and wedge
Durability testing (unrecorded)

Axe-head: 5160 casted steel, blued to seal
Shaft: Hickory with walnut danish oil (not linseed oil, that was only the test models)
Wedge: Hickory with walnut danish oil

Student Team:
Caden Grimmett (team leader)
Sam Morris
Ethan Michael Altenbauer
Channing Woodson
Andrew (Bo) Grace

References

Historic References

https://www.futuremuseum.co.uk/collections/people/lives-in-key-periods/renaissance--reivers-the-reformation/border-reivers/battle-axe

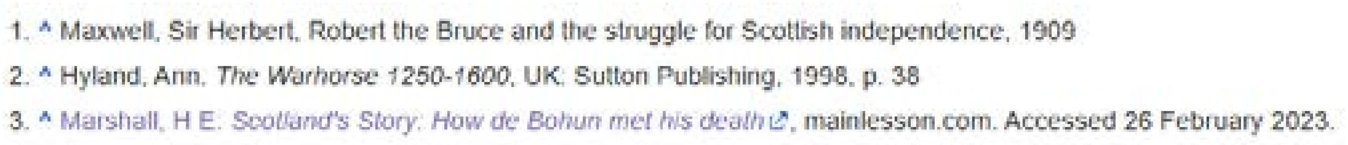
http://www.nndb.com/people/593/000114251/

https://www.scotsman.com/arts-and-culture/mystery-of-robert-the-bruce-statue-teeth-solved-1528647

https://www.youtube.com/watch?v=G4dBCPyCuyE&t=114s

https://www.metmuseum.org/art/collection/search/22139

bro none of these links work anymore...



1. ^ Maxwell, Sir Herbert, Robert the Bruce and the struggle for Scottish independence, 1909
2. ^ Hyland, Ann, *The Warhorse 1250-1600*, UK: Sutton Publishing, 1998, p. 38
3. ^ Marshall, H E. *Scotland's Story: How de Bohun met his death*, mainlesson.com. Accessed 26 February 2023.

Faculty Sponsor/Advisor:
Tim Arquitt

Special Thank you to Southern Cast Products for letting us utilize your facilities!

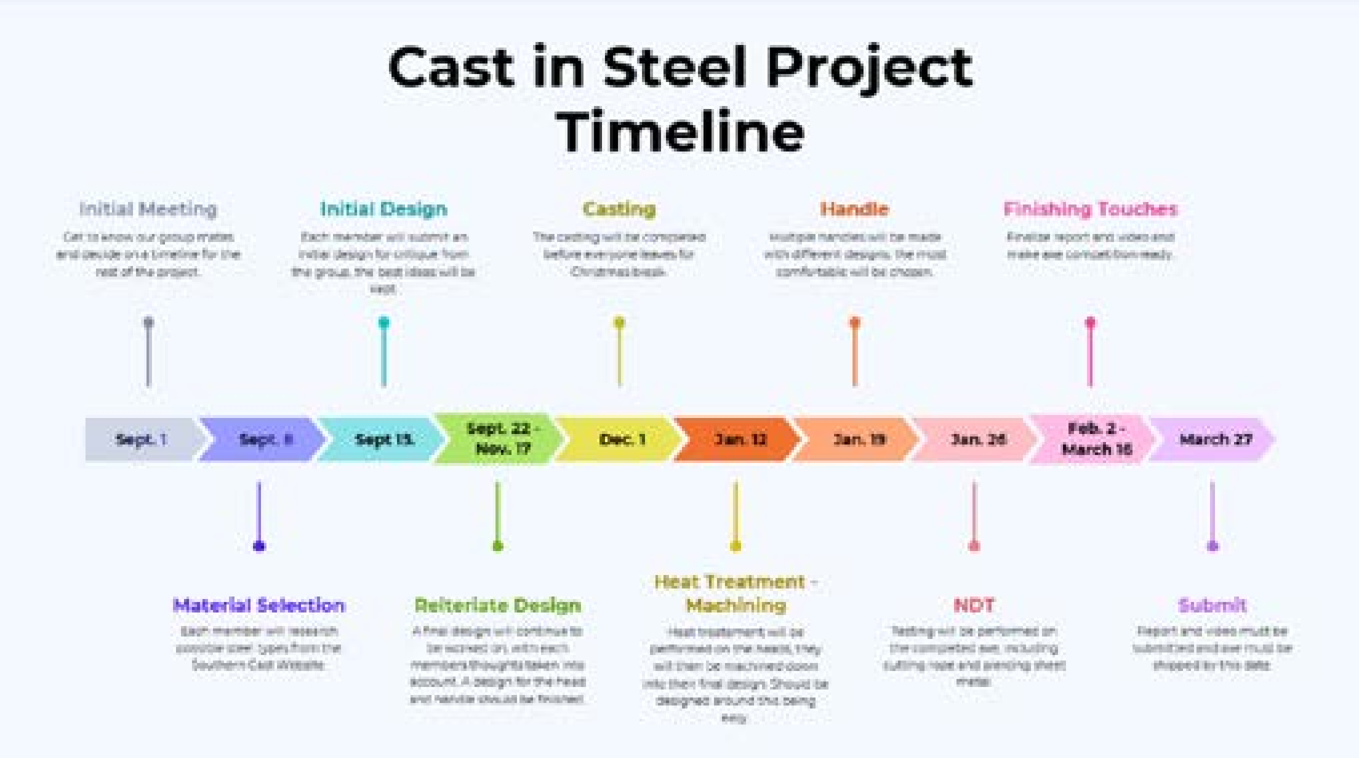
Special Thank you to Arkansas State Univerisity, Society of Manufacturing Engineers, and Honor's College for assisting us with this opportunity!

(Also Thank you to Michael Alexander of the Garage, and Robby Davenport of the Machine Shop!)

https://cdn.sfsa.org/wp-content/uploads/2025/06/castinsteel2026.pdf?x94350

Appendix 1

Introduction and Material Selection



Cast in Steel Project Timeline

Initial Meeting
Get to know our group mates and decide on a timeline for the rest of the project.

Initial Design
Each member will submit an initial design for critique from the group, the best ideas will be kept.

Casting
The casting will be completed before everyone leaves for Christmas break.

Handle
Multiple handles will be made with different designs, the most comfortable will be chosen.

Finishing Touches
Finalize report and video and make axe competition ready.

Sept. 1 · Sept. 8 · Sept 15 · Sept. 22 - Nov. 17 · Dec. 1 · Jan. 12 · Jan. 19 · Jan. 26 · Feb. 2 - March 16 · March 27

Material Selection
Each member will research possible steel types from the Southern Cast Website.

Reiteriate Design
A final design will continue to be worked on, with each members thoughts taken into account. A design for the head and handle should be finished.

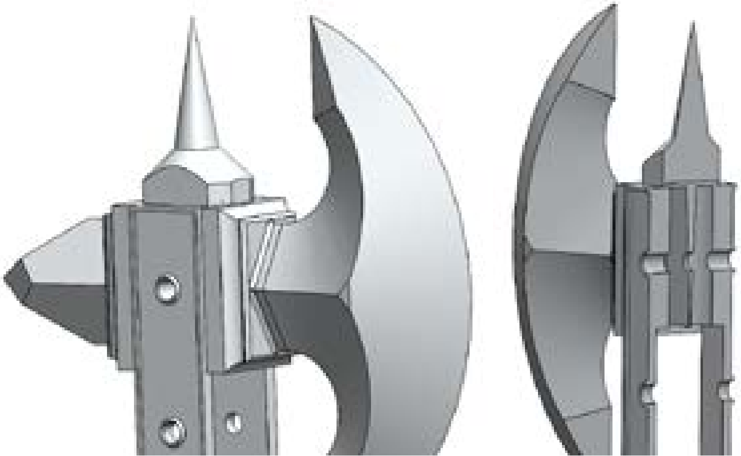
Heat Treatment - Machining
Heat treatment will be performed on the heads, they will then be machined down into their final design. Should be designed around this being easy.

NDT
Testing will be performed on the completed axe, including cutting rope and piercing sheet metal.

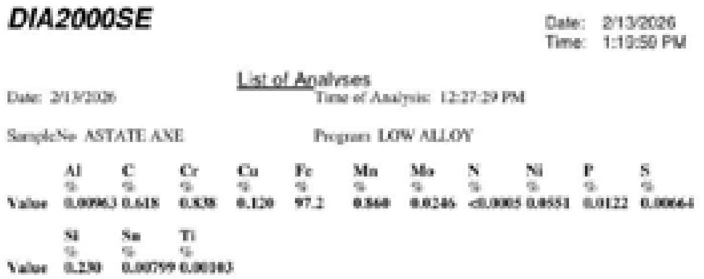
Submit
Report and video must be submitted and axe must be shipped by this date.

Appendix 1A Project Timeline for processes and submission 2026

Appendix 1B Prototype Axe



Appendix 1C Prototype Axe with separate wedge-pike component, as designed in SolidWorks



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DIA2000SE                                              Date:  2/13/2026
                                                       Time:  1:10:50 PM

                          List of Analyses
Date: 2/13/2026                  Time of Analysis: 12:27:29 PM

SampleNo ASTATE AXE              Program LOW ALLOY

       Al      C     Cr     Cu     Fe    Mn     Mo      N        Ni     P      S
       %       %     %      %      %     %      %       %        %      %      %
Value  0.00963 0.618 0.838  0.120  97.2  0.860  0.0246  <0.0005  0.0551 0.0122 0.00664

       Si      Sn      Ti
       %       %       %
Value  0.230   0.00799 0.00103
```

Appendix 1D Alloying elemental composition data for the final product axe heads

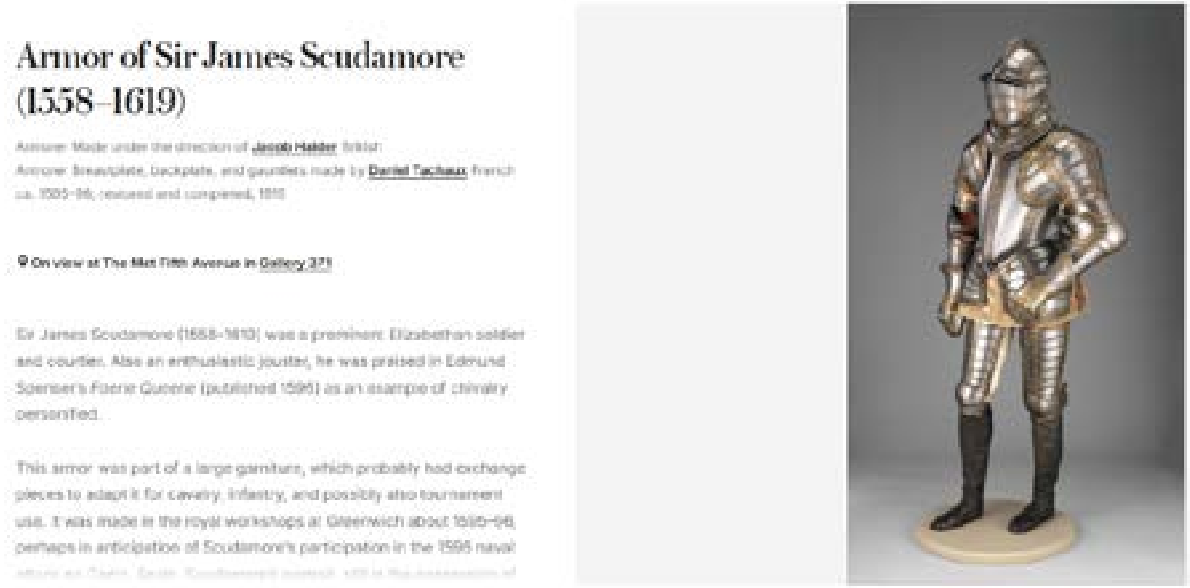
Appendix 2

Historic References

Appendix 2A Watercolor depiction of Robert the Bruce and Henry De Bohun in combat.

The equestrian statue of Robert the Bruce, by Pikington Jackson (1964) before 2008 restoration depicts Robert with a pike-less battle-axe.

Robert the Bruce depicted in popular culture, as an ally of William Wallace in Braveheart (1995)



Armor of Sir James Scudamore (1558–1619)

Armorer: Made under the direction of Jacob Halder British

Armorer: Breastplate, backplate, and gauntlets made by Daniel Tachaux French

ca. 1595–96, restored and completed, 1915

On view at The Met Fifth Avenue in Gallery 371

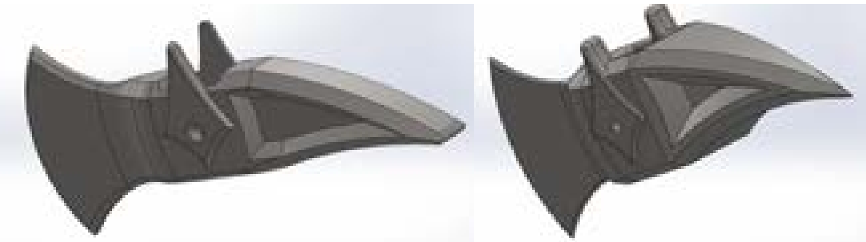
Sir James Scudamore (1558–1619) was a prominent Elizabethan soldier and courtier. Also an enthusiastic jouster, he was praised in Edmund Spenser's *Faerie Queene* (published 1596) as an example of chivalry personified.

This armor was part of a large garniture, which probably had exchange pieces to adapt it for cavalry, infantry, and possibly also tournament use. It was made in the royal workshops at Greenwich about 1595–96, perhaps in anticipation of Scudamore's participation in the 1596 naval

Appendix 2B Armor of Sir James Scudamore considered as our initial gothic stylistic inspiration

Appendix 3

Design


Appendix 3A reduction of initial axe design from adze to pick form


Appendix 3D Initial Prototype Liberal Design


Appendix 3B Final Form of Design A


Appendix 3C Unused prototype design with pin


Appendix 3E Various 3D printed prototype axe heads


Appendix 3C Unused Prototype Liberal Design 3D print


Appendix 3C Simulation Mesh of unused prototype with pin

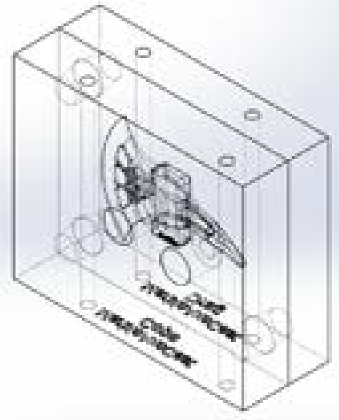

Appendix 3F Final Design of Liberal Design B


Appendix 3G Design A initial shaft design for mass and simulation rendered in SolidWorks

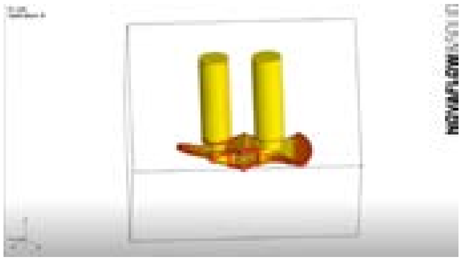
Appendix 4

Casting Design

Appendix 4A Risers added to Design B prior to creating casting model

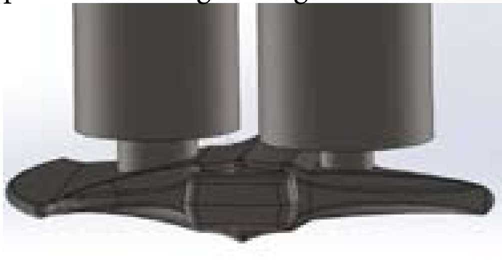


Appendix 4B Mold model for Design B (final choice)



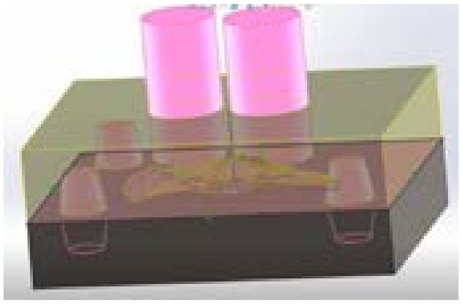
Appendix 4E Near-Final phase of pour in simulation (Design A)

Appendix 4F Earliest phase of pour in simulation (Design A)



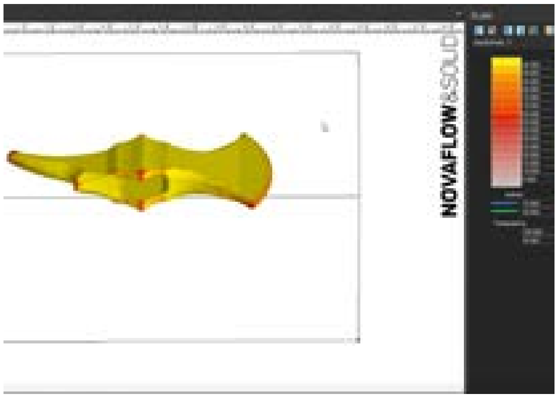
Appendix 4C Risers added to Design A prior to creating casting model

Appendix 4D Mold model for Design A (original)



Appendix 4G Fluid simulation for casting mold of Design A

Appendix 4I uncut casting of Design B removed from sand mold



Appendix 4H Stress test simulation for casting mold of Design A

Appendix 5

Casting mold and Film


Appendix 5A Ceramic direct-pour and ceramic risers used for the casting pour with a filter in it's center circumference

Appendix 5B fully-prepared-for-pour drag and cope of Design A


Appendix 5C SFSA Cast in Steel film crew arrives. Channing waits while Bo is filmed


Appendix 5D Sand-cast mold of Design A

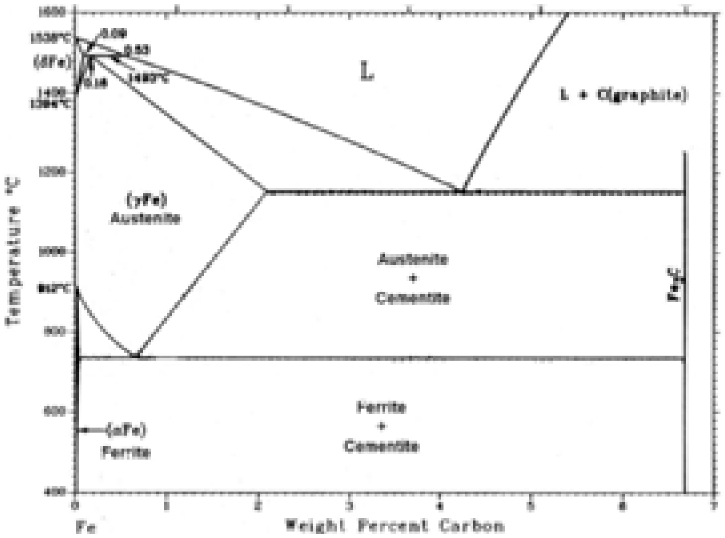

Appendix 5E Sand-cast mold of Design A


Appendix 5F Design A mold cooling after direct pour


Appendix 5F (close up) Design A mold cooling after direct pour

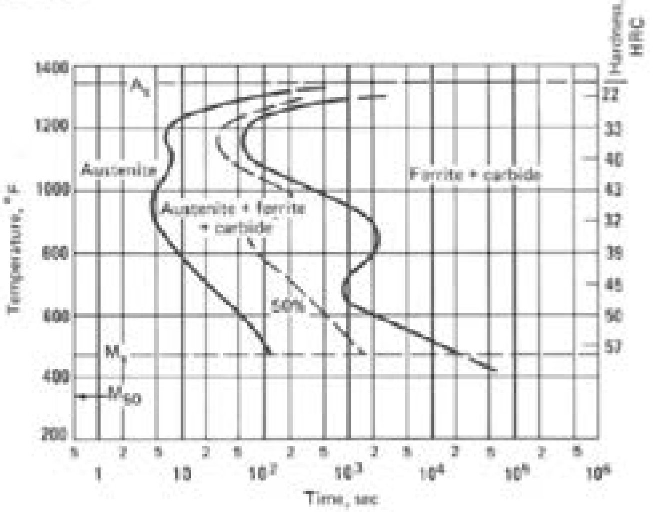
Appendix 6

Heat Treatment Graphs



Appendix 6A Steel heating and composition chart for 5160 steel

5160: Isothermal Transformation Diagram. Composition: 0.61 C, 0.94 Mn, 0.88 Cr, 0.22 Mo. Austenitized at 845 °C (1555 °F). Grain size 7



Appendix 6B Isothermal transformation chart for cooling/hardening

Appendix 6C Axes being taken to heat treatment

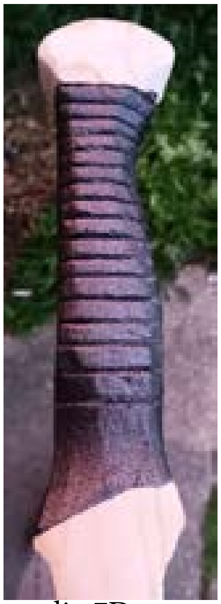
Appendix 7

Grip/Assembly

Appendix 7A Test attempt that failed critically during undocumented field testing.

Appendix 7B Non-ambidexterous ergonmic concept grip

Appendix 7C Ergonmic concept grip with enamel



Appendix 7D Ergonmic concept grip with enamel

Appendix 7E Ambidexterous forward-curved Adirondack-style axe choice, similar to final design.

Appendix 7F Adirondack-style axe prototype, that wasn't set quite right yet. This model featured a loop for a tassel or chain.

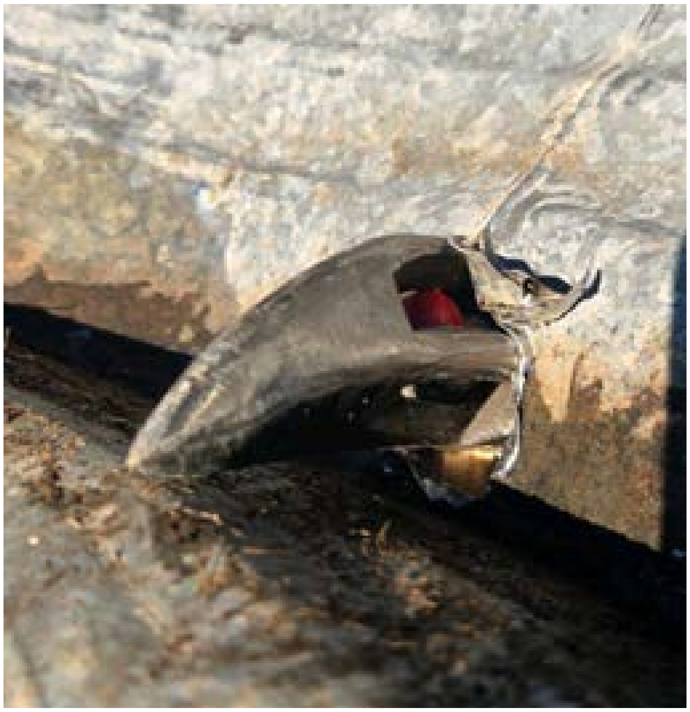
Appendix 8

Field Test

Appendix 8 Weldment of cracked Design B Axe head immediately after weldment.

Appendix 8 Previously cracked Design B Axe head after grind and polishing.

Appendix 8 Field test 1, Design B with Oak shaft tested on sheet galvanized sheet metal. (front)



Appendix 8 Field test 1, Design B with Oak shaft tested on sheet galvanized sheet metal. (rear)

Appendix 9

Final Product

Appendix 9A Final Axe Assembly driven into a log

Appendix 9B Two final axes displayed together for comparison.

Appendix 9C Set of finalized axes arranged by length