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

Texas State University– Equestrian Edge Engineers

Team Members:

Alex Gerstacker

Austin Kenyon

Antonio Castro-Rodriguez

Tristen Nichols

Advisor(s) Name:

Dr. Luis Trueba

Foundry Partner:

Texas State University AFS

Texas State University

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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. Our team's goal is to design and manufacture a historically accurate horseman's battle axe. Our vision is to design an axe that balances historical design, functionality, and manufacturability. Our approach for creating this axe is to combine authentic form with modern casting and engineering methods. If we succeed, we will have made an axe that is visually appealing, while also being durable and ergonomic.

Historical Accuracy

We decided to base our design from the axe wielded by Robert the Bruce. Robert the Bruce was born on 11 July 1274, but nobody knows where for sure. An educated guess would be Turnberry Castle in Ayrshire, where he was raised to speak three languages – Gaelic, Scots and Norman French – and to fight for his family's claim to the Scottish crown. On his father's side, the Bruce family had its roots in Normandy – a Robert de Brus had come to England with William the Conqueror's army. Robert's mother Marjorie was the Countess of Carrick and descended from an ancient Gaelic bloodline. After the death of Alexander III in 1286 there was no direct heir to the throne in Scotland. King Edward I of England was asked to choose between the two main claimants – Robert's grandfather and John Balliol, who both claimed descent from David I. He gave the crown to John Balliol. Robert and his father refused to recognize Balliol as their king, and in 1296, when Edward I turned on Balliol and invaded Scotland, they gave their support to the English. Robert switched allegiance more than once in his life – showing that his actions were not always purely patriotic, and that he would do whatever it took to achieve his ambitions.

Casting Technology

The software we used for all CAD designs was Fusion 360. The model 3D printer we used to print all our trial and final patterns was a Bambu p1p. We found this method to be extremely effective for adjusting the pattern geometry in a very short time. We uploaded our designs from Fusion to Inspire Cast to simulate the casting of our piece. This stage we found to be the most difficult.

Throughout the entire design phase, we had to adjust the design of both our gating system and our pattern multiple times. In between these changes, we would run simulations in Inspire Cast. These simulations sometime spanned multiple hours, and often would not complete due to discontinuities detected by Inspire Cast. We decided to simplify our design as much as we could. This meant taking away the Celtic symbol on the blade and deleting many draft angles. Our foundry professor, Dr. Luis Trueba, advised that the simulation produced from this will be similar enough to apply the results to our real-world casting. This decision allowed Inspire Cast to run without calculating several vertices, so the simulations ran smoothly after this.

After eliminating as many possible defects in Inspire cast as we could, we poured the axe heads with 5160 spring steel. We used a resin sand mold. We used our campus foundry for all our pours. The furnace we have on campus is an Inductotherm Power-Trak (shown in figure 1). Before pouring our molten steel mixture into our molds, we poured coins to be analyzed so we could achieve our desired chemistry. To analyze our coins we used a Spectromaxx Optical Emission Spectrometer. Our target composition was .55 - .65 Carbon, .65 - 1.1 Manganese, .2 - .35 Silicon, and .6 - 1.0 Chromium.

(Figure 1)

Design & Planning Phase

Our research began with historical data on the horseman's axe. We researched axes held in different museums to find similarities and differences from a variety of locations. We viewed some more modern horseman's axe creations and the techniques used to create them. We also consulted our school's library to find information on Robert the Bruce, and depictions of Robert with his horseman's axe. Our research led us to lean more toward modern design decisions than historically accurate design decisions, while still having the key features of the historical horseman's axe. We believe that this approach will result in an extremely durable and ergonomic axe. After collecting information about a variety of historical and modern designs, we began brainstorming ideas.

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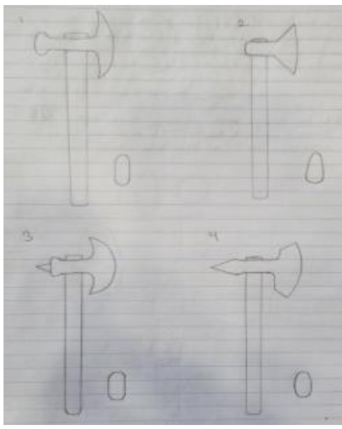
We began the brainstorming process by creating a Quality Function Deployment matrix. This matrix assigns a measurable metric to the customer's needs. The customer needs in this case would be the desired qualities we are looking for in the horseman's axe we are to create. This design matrix also weighs the importance of each desired quality. Some of these qualities include blade edge retention, aesthetics, ergonomics, and penetration ability. Some of the metrics assigned to these qualities were length, weight, metallurgic composition, and hardness. This matrix informed our decision making when selecting concepts for each component of the axe.



	Overall Concept								
Weight	Evaluation Criteria	#1	Weighted Score	#2	Weigthed Score	#3	Weighted Score	#4	Weighted Score
10.00%	Wieldability with one Hand	-		-		-		-	
15.00%	Recoverability	4	0.6	2	0.3	4	0.6	3	0.45
5.00%	Majority of features attained through casting	1	0.05	3	0.15	3	0.15	3	0.15
10.00%	Aesthetics	2	0.2	1	0.1	3	0.3	4	0.4
15.00%	Blade Edge Retention	3	0.45	2	0.3	2	0.3	3	0.45
15.00%	Durability	4	0.6	2	0.3	3	0.45	4	0.6
7.50%	Ability to cut through wood	2	0.15	3	0.225	4	0.3	4	0.3
7.50%	Steel penetration ability	2	0.15	1	0.075	4	0.3	4	0.3
15.00%	Ergonomics	2	0.3	4	0.6	2	0.3	3	0.45
	Total Score		2.5		2.05		2.7		3.1
	Rank		3		4		2		1
	Continue?		No		No		No		Develop

(Figure 2)

Figure 2 shows four concepts we brainstormed. The overall concepts we created are based on criteria selected for each sub-concept. These selection criteria are heavily based on the desired qualities of the horseman's axe. Some of the criteria include recoverability, durability, ergonomics, and aesthetics. After ranking sub-concepts, we were able to compile them into the 4 complete concepts shown in figure 2. We decided to move forward with concept #4.

Making the Axe

After deciding on a concept to develop, we began planning how we were going to create our pattern. We were recommended by our foundry professor to 3D print a pattern. We designed our pattern in Fusion 360 and used a Bambu p1p 3D printer to print prototypes of our pattern. Once we printed a pattern we were happy with, we began designing and calculating the dimensions of our gating system. The right photo in Figure 3 depicts one of our first fill simulations in Inspire Cast.

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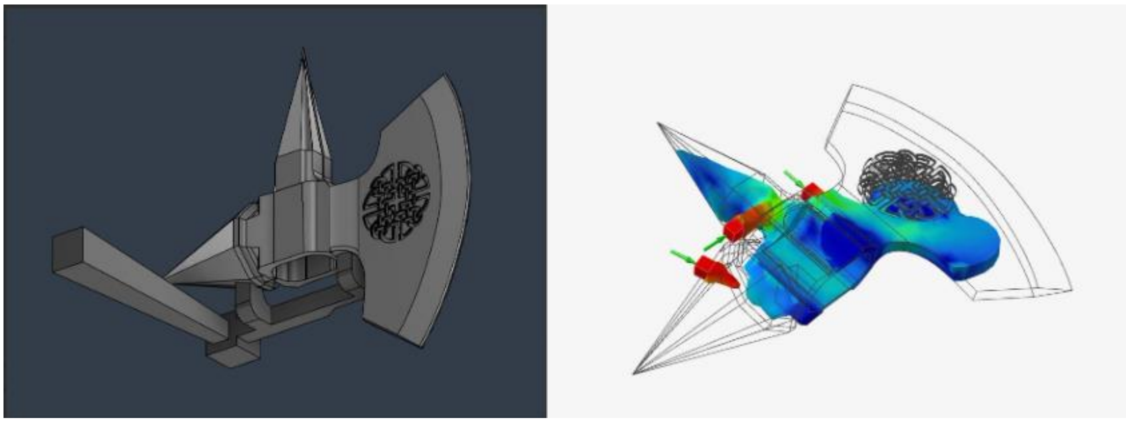

(Figure 3)

One of our foremost challenges was making the weight limit. The design of our axe head requires a bit more of a robust haft, that if casted would be heavier than if we decided to use wood for the haft. Our research has led us to believe that we should use hickory wood for the haft. Hickory is a very durable wood, and the weight we will save, using wood opposed to casting steel, will keep us under the limit. We believe our next biggest challenge will be cold shutting around the eye of the axe head, and possible porosity toward the blade edge and tip of the spike. Our plan was to pour multiple castings and make adjustments in pattern design and gating systems as needed.

Non-Destructive Testing

Once we poured our final three axe heads we took them to the Southwest Research Institute located in San Antonio, Tx. Here we had all three heads radiographed. The x-ray results showed wormhole porosity in two out of three heads. We have selected the axe head without this porosity as our axe that we will submit for the competition.

Results

We successfully cast three axe heads using 5160 spring steel in our campus foundry with the Inductotherm Power-Trak furnace. After chemistry verification with the Spectromaxx Optical Emission Spectrometer, all pours met our target composition. We kept the final axe head design simple enough for reliable simulation in Inspire Cast while still including the key historical features: a short overall length, heavily curved bearded blade, rear spike, and top spike. After non-destructive testing at Southwest Research Institute in San Antonio, Texas, the radiography results showed wormhole porosity in two of the three heads. We selected the third head, which was free of visible internal defects, as our competition submission. We then tempered the axe for 2 hours at 500 degrees Fahrenheit. We then sharpened the blade and finished the surface using a belt sander. We fitted it with a hickory wood haft utilizing a snug fit and epoxy. Our axe weighs 3.03lbs and is 20.5in in length. The finished axe maintains the strong historical form of a horseman's battle axe with modern improvements in durability and handling.

Final Thoughts

This project taught us a lot about the real challenges of steel casting. Using Fusion 360 for design and the Bambu P1P for fast pattern iterations worked extremely well and let us make quick changes. The biggest struggle was getting Inspire Cast simulations to run without crashing. Simplifying the pattern by removing the Celtic symbol and many draft angles made the simulations reliable, and our foundry professor Dr. Luis Trueba was right that the results were still useful for predicting real-world issues. We learned that cold shuts around the eye and porosity near thin sections like the blade edge and spike tips are common risks with this type of complex geometry. Multiple design adjustments to the gating system helped, but we still saw wormhole porosity in two castings. Radiography at Southwest Research Institute was very valuable for choosing a sound axe head. Overall, we are proud of the final axe. It balances historical accuracy with practical functionality and modern manufacturing methods. The combination of 5160 steel, good chemistry control, and a hickory haft should give us a durable, ergonomic weapon that performs well. If we could do it again, we would start gating simulations even earlier and maybe test a few more riser or filter options to further reduce porosity risk. This competition pushed us to apply classroom knowledge in a real foundry setting and showed the importance of iteration, simulation, and thorough testing. We are grateful for the guidance from Dr. Trueba and the opportunity provided by SFSA.

Resources

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