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

The University of Alabama – The Elephant Jockeys

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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. To this end, we created a modern recreation of a historical type of axe using 3D printing technology, induction melting, and phenolic urethane sand molding. Through non-destructive testing, we have demonstrated that our axe is capable of performing well in its intended applications.

Historical Background

In the Middle Ages, as plate armor technology improved, the effectiveness of a sword against armored opponents decreased. For an armored rider on horseback who may need to attack an armored opponent, a sword may become nearly useless. To solve this problem, blunt and piercing weapons were specifically employed for mounted combat. One such weapon was the horseman's axe. Typically, a horseman's axe has an axe blade for cutting or cleaving and a pick for stabbing. Some designs included a spike on the top for utility similar to that of a spear.

Design and Production

This type of product is traditionally forged due to its complex geometry. We used casting, as modern casting techniques can approximate the properties of traditionally forged parts. When considering other options, milling would require an extremely large starting block and excessive machining time. The geometry of the axe also rules out extrusion and drawing.

Initial Design

The axe consists of a handle, pommel, tapered shaft, axe head, spike, and pick. A two-runner gating system was designed, and the entire casting was simulated using MAGMA software. The simulation results indicated that the mold would likely fill completely, with low predicted porosity.

Next, the casting model was divided into a cope and drag. The pattern components were printed using an FDM printer in PLA. The resulting pieces were mounted to a wooden board, forming a matchplate pattern.

Sand molds were then created using a phenolic urethane resin process with silica sand. Other available processes were not suitable for steel. Our investment shell systems could not be preheated sufficiently to prevent cold shuts, and they suffered from poor temperature resistance. For the resin sand molds, the interior of the mold was coated with an alcohol-based zircon paint to reduce potential burn-in. The mold was glued, weighted, and fitted with a pouring cup.

Figure 1: Assembled Molds Before Pouring.

Initial Pour

Around 80 lb of nominally 1060 steel was melted in a coreless induction furnace and poured into sand molds for the axe. The resulting axes from the initial pour exhibited significant defects. All castings exhibited misruns, with only the first axe poured close to usable. After some finishing, the best axe was found to have a hot tear at the interface between the head and the shaft, which rendered it unusable. In addition to the casting issues, the poured material had a carbon content of 1.0 wt%. This was likely due to a cast iron return being added to the heat instead of a carbon steel return.

Figure 2: Castings with Defects.

Figure 3: Hot Tear Detail.

Redesign

To address misruns, the flange and web thickness of the “I-beam” were increased, the overall length was decreased, and the targeted pour temperature was increased by ~50 °C. To address hot tears, the resin content of the sand was reduced by ~10%, and the shakeout time was increased to 16 hours, compared to 30 minutes for the first heat. To address the high carbon content, we decided to use only plate steel, ferromanganese, and pig iron for the next heat. Additionally, the plate steel has a variable carbon content, averaging approximately 0.3 wt%. We therefore targeted 1080 steel for the next pour, as achieving 1060 steel was unlikely with the available charge materials.

The previous steps were repeated for making sand molds, except a loose piece was used instead of a cope/drag, to reduce print times due to limited time. A second pouring cup was added to the mold on top of the main riser to allow for more head pressure in the open riser.

Figure 4: Prepared Loose Piece Pattern.

Figure 5: Assembled Molds Before Pouring.

Final Pour

A heat consisting of 70 lb of plate steel, 0.6 lb of ferromanganese, and 7 lb of pig iron was melted in an induction furnace. A chemistry sample was taken after the entire charge was molten. After deoxidation with 21.6 g of aluminum shot, the ~1650 °C steel was poured into a preheated ladle and then into the mold. The resulting chemistry was within the target ranges for 1080 steel. Elevated levels of Co and Ni occurred likely due to the previous heat in the furnace containing significant amounts of these elements. The presence of Cu and Cr was likely due to the non-uniform composition of the plate steel, with some pieces containing significant quantities of those elements.

Finishing

Figure 6: Initial Casting Before Finishing

After shakeout, a plasma cutter was used to remove the gating system from the axe. A sandblaster was used to allow easy inspection of the surface for cracks. No cracks were observed. The axe was then stress-relieved in a forge to reduce internal stresses and the likelihood of crack propagation. The remaining flashing and gating system were removed with a combination of belt sanding and angle grinding. The primary bevel was ground with a belt sander. At this point, we removed the top spike to allow the axe to fit into the quench tank. Additionally, the handle was forged out and a plate was welded to its base.

Figure 7: Axe After Cutoff

The axe head was heated in a forge and then oil quenched. This results in a tougher, more ductile shaft while maintaining sufficient hardness at the cutting surfaces to hold an edge. The axe was tempered with a handheld torch. Finally, the handle was wrapped in paracord and hockey tape.

Testing

The finished axe was visually inspected for cracks; none were found. The blade and pick of the axe were tested against wood, 16-gauge steel, and cinderblocks. No visible damage was observed during testing.

Figure 8: Plate Punctured by Axe

Final Result

Weight: 3.27lb

Length: 21.5”

Material: 1080 steel.

Cost Estimate

Below is copied from a modified version of our foundry's cost estimation spreadsheet.

			Molds per Heat	3		
			Parts per Mold	1		
	# People Working	Molds/Hr	Hourly Rate	Rate plus OH	Cost per Mold	Cost per Part
Mold making	1	3	15	18.75	6.25	6.25
Melting	# People Working	Heats per Hour	Hourly Rate	Rate plus OH	Cost Per Heat	Cost per Part
	4	0.5	15	18.75	150	50
Finishing	#People Working	Pieces/Hr	Hourly Rate	Rate plus OH		Cost Per Part
	1	0.25	15	18.75		75
	kWh Per pound	Cost/kwh				Cost Per Part
Power/kWh	0.3	0.08				0.6
	Cost/lb	Weight of Casting				
Alloy Cost/lb	~1	25				25
					Total cost per pt	156.85
					Overhead 30%	203.91

Chemistry

Measurement Results

Instrument	78E1032		
Sample	axe 3-13		
Alloy	FE_100	Mode	Element Concentration	13.03.2026 15:38:14

	Fe [%]	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]
1	96.56	0.7521	0.0264	0.7274	0.0162	0.0064	0.3292
2	96.47	0.7667	0.0525	0.7494	0.0167	0.0062	0.3312
3	96.53	0.7552	0.0251	0.7330	0.0164	0.0062	0.3310
⇑ Ø ⇓	**96.52**	**0.7580**	**0.0347**	**0.7366**	**0.0165**	**0.0062**	**0.3305**
SD	0.047	0.00769	0.01547	0.01146	0.00026	0.00014	0.00111

	Mo [%]	Ni [%]	Al [%]	Co [%]	Cu [%]	Nb [%]	Ti [%]
1	0.0826	0.9492	0.0039	0.2132	0.1961	0.0135	0.0013
2	0.0848	0.9541	0.0124	0.2135	0.1982	0.0150	0.0056
3	0.0840	0.9576	0.0030	0.2141	0.1997	0.0135	0.0012
⇑ Ø ⇓	**0.0838**	**0.9536**	**0.0064**	**0.2136**	**0.1980**	**0.0140**	**0.0027**
SD	0.00112	0.00420	0.00521	0.00050	0.00178	0.00086	0.00250

	V [%]	W [%]	Pb [%]	Sn [%]	Zr [%]	Zn [%]	N [%]
1	0.0042	0.0793	0.0023	0.0068	0.0016	0.0035	0.0086
2	0.0042	0.0801	0.0015	0.0067	0.0014	0.0030	0.0119
3	0.0041	0.0792	0.0020	0.0069	0.0017	0.0033	0.0091
⇑ Ø ⇓	**0.0042**	**0.0795**	**0.0019**	**0.0068**	**0.0016**	**0.0033**	**0.0099**
SD	0.00008	0.00046	0.00039	0.00007	0.00016	0.00027	0.00177

	Se [%]	B [%]	Ca [%]	Bi [%]	As [%]	Ta [%]	Sb [%]
1	0.0011	0.0004	0.0016	0.0010	0.0045	0.0089	0.0029
2	0.0012	0.0003	0.0021	0.0010	0.0042	0.0075	0.0036
3	0.0013	0.0004	0.0014	0.0013	0.0045	0.0082	0.0024
⇑ Ø ⇓	**0.0012**	**0.0004**	**0.0017**	**0.0011**	**0.0044**	**0.0082**	**0.0030**
SD	0.00011	0.00004	0.00033	0.00018	0.00017	0.00071	0.00059