

# SFSA Cast In Steel 2026 – Horseman's Axe

## Technical Report

Louisiana Tech University – Bayou Bulldogs



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### **Abstract**

“SFSA has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available.”

By participating in SFSA’s Cast in Steel, the Bayou Bulldogs hope to raise awareness about the foundry industry and pique interest at Louisiana Tech University. Additionally, through spurring interest, the team hopes to create a Foundry or Cast in Steel club at Tech.

### **Background**

During the Battle of Bannockburn in 1314, Robert the Bruce, King of Scotland, famously defeated Henry de Bohon in single combat with an axe. It has been assumed that the axe used was a Horseman’s Axe. However, the distinct horseman’s axe did not appear until the 15th century. This period coincided with the height of full plate armor development. Advanced armor rendered the knight’s sword, their primary weapon, almost useless. As a result, warriors turned to other weapons better suited for piercing and impact. Most new weapons lacked the sword’s elegance, but the horseman’s axe stood out as an exception. Many of these axes featured ornate designs and craftsmanship similar to sword hilts and armor. Horseman’s axes were engineered for combat effectiveness. They usually had a short, curved front blade and a hammer or spike, often called a pick, at the rear. Many also had a top spike. The force of these axes, whether by impact or puncture, could devastate opponents. Medieval battle axes proved vital in both individual duels and large battles. Infantry and cavalry both used various types of axes. Infantrymen often used smaller, one-handed axes for speed and agility. Heavily armored warriors or specialized units preferred larger, two-handed versions. A major strength of the battle axe was its armor penetration. The axe’s weight and force could crack or puncture even thick armor. The curved blade concentrated force, much like a mace, producing destructive results.

### **Design**

#### **A Definition**

Now that the background had been established, it was essential to analyze how the information translated into the design and creation of a Horseman’s Axe. It was necessary to define what one is. The Bayou Bulldogs defined what constitutes a Horseman’s Axe according to two (2) stipulations:

- a) Must be a battleaxe
- b) Must be suited for use from horseback

Those stipulations meant that the axe must be designed specifically for combat rather than for chopping wood. The requirements dictate a combat axe, which differs from a wood axe as follows: wood axes have a thick, wedge-shaped head to split wood, while battle axes have a thin, sharp blade designed to cut through softer targets. Wood axes are heavier to maximize momentum when splitting, whereas battle axes are lighter and more balanced for quick movements in combat. Handle length also varies for practical reasons—wood axes tend to have longer handles, while battle axes may have shorter shafts for increased handling control. For cavalry, the axe must be balanced and light enough for one-handed use, enabling the wielder to retain control of a horse. In addition, the build must meet two contest-specific requirements:

1. No more than 3.3 pounds
2. Less than 31.5 inches in overall length

## Materials

Originally, the team considered 9260 but ultimately chose D2 tool steel. This steel (also known as SKD11, 1.2379, and Hitachi SLD) is a high-carbon, high-chromium, air-hardening tool steel noted for achieving high hardness and strong wear resistance from abundant chromium-rich carbides. While some steels offer greater toughness or wear resistance, D2 balances wear resistance, toughness, performance, and price (Hudson Tool Steel Corporation). Common applications include rolls, punches, blanking, forming, and trimming dies, thread rolling dies, shear and food-processing knives, and gauges.

The development of D2 steel coincides in part with the invention of stainless steel and high-speed steel. D2 is part of a tool steel category called “high carbon, high chromium” steels. The production of chromium-alloyed steel wasn’t practical until ferrochromium was developed in 1821 and, more practically, in 1895 with the development of low-carbon ferrochromium. The first commercially produced steel with a chromium addition was in 1861 by Robert Mushet, the inventor of the first tool steel. A patent on chromium steel was granted to Julius Baur in New York in 1865. Robert Hadfield reported on the properties of chromium-alloyed steels in 1892, also covering high-carbon, high-chromium steels, which were in their infancy. However, he concluded that the forgeability of the alloys was poor, often resulting in cracking, and that steel with 1.27% C and 11.13% Cr was at the limit of forgeability. In 1918, Paul Kuehnrich filed a patent in England for a high-carbon, high-chromium steel modified with approximately 3.5% cobalt. The cobalt addition was intended to improve the hot hardness of the steels, making them closer to high-speed steel. The patent has fairly broad chemistry ranges: 1.2-3.5% carbon, 8-20% chromium, and 1-6% cobalt. However, interestingly, the example alloy given had 1.5% C, 12% Cr, and 3.5% cobalt, which, without the cobalt, would be very close to modern D2. Its relatively high wear resistance, along with good hardness and toughness, made it work well as a knife steel. D2 has somewhat better wear resistance and toughness than 440C, the most commonly used stainless steel in the 70’s, so for makers who felt that the stain resistance of D2 was “good enough,” it could offer superior properties. It also had much greater wear resistance than the carbon steels commonly used by forging bladesmiths, so it was adopted by some knife makers seeking a high-wear-resistant steel. D2 has since been used in many knives, with edge retention of D2 along with other steels, with CATRA testing, and found it to be somewhat better than N690, ATS-34/154CM, and 440C, on par with 3V, but worse than S35VN, Vanadis 4 Extra, Elmax, S30V, M4, and M390.

By 1934, a composition consistent with D2 was discussed with 1.55% C, 12% Cr, 0.25% V, and 0.8% Mo. The molybdenum was added to make it a true “air hardening” steel, allowing it to fully harden in thick sections or without oil. The vanadium addition was made to improve toughness, which it does by refining both the grain size and the carbide structure. This new D2-type steel was gaining in popularity because of its air hardening property, low distortion and better machining quality than the other high carbon, high chromium steels.

The steel was first used in knives by D.E. Henry in 1965 or 1966, and it became popular. Spray-form and powder-metallurgy versions have been produced to improve toughness and refine the microstructure of D2. D2 has good wear resistance, hardness, and adequate toughness. D2 has ~11-12% chromium and is sometimes called a “semi-stainless” because it is assumed that, with such a high chromium content, it must be very close to stainless. However, because of its high carbon content (1.55%), a good portion of that chromium is used up in carbides rather than being in solution.

Steel	Hardness (Rc)	Edge Retention	% of 440C
M390	61+	958.6	179
Elimax	62	930.7	174
M4	61	899.7	168
S30V	61	798	149
Vanadia 4 Extra	61	708.9	132
S35VN	61	706.6	132
3V	61	674.4	126
D2	61	665.8	124
N690	61+	635.1	118
ATS-34/154CM	61+	646.9	102
440C	59	536	100

Steel	Hardness (Rc)	Toughness (ft-lbs)	Joules
S7	57	125	165
3V	60	70	95
A2	60	40	53
CPM M4	62	32	43
CruWear	62	30	40
D2	60	21	28
M2	62	20	27
S90V	58	19	26
440C	58	16	22

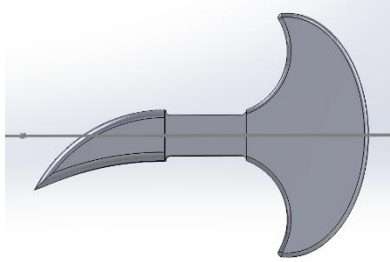
## Modeling

While Horseman's axes can come in various sizes, styles, and designs, with some having a hammer instead of a pick or a more squarish blade, the team decided to base their axe design after Arms and Armor's Horseman's Axe.

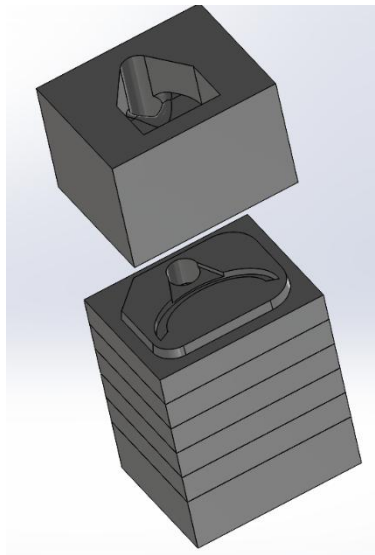
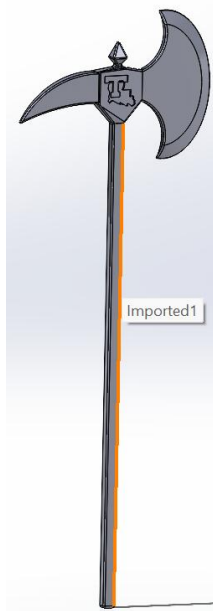


[https://myarmoury.com/review\\_aa\\_haxe.htm](https://myarmoury.com/review_aa_haxe.htm) 1

It took many iterative modeling sessions to perfect the blade shape, with the blade either having the wrong curvature or lacking the correct clearance from the handle and top point, thus interfering with/touching the shaft.



At first, the team envisioned a bold, modern two-part axe—complete with a special coating and a synthetic handle injection-molded around the head, much like the Fiskars X37. Upon reaching out to several companies, they only ran into obstacles of time, cost, and availability. Aluminum seemed promising, yet concerns over weight and shock absorption lingered. Ultimately, they decided it would be best to go with a classic wooden handle, drilled and epoxied to the shaft, thus blending tradition with their innovative spirit.



### **Analysis**

Once a final design for the axe had been reached, several videos of natural analysis were created to determine proper riser placement, in addition to using Chvorinov's rule. Additionally, stress analysis was completed, revealing that it would take almost 10,000 Newtons to cause the axe to break.

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### Chvorinov's rule

**Chvorinov's rule** is an applied physics relationship first expressed by Czech engineer Nicolas Chvorinov in 1940,<sup>[3]</sup> that relates the solidification time for a simple casting to the volume and surface area of the casting. In simple terms the rule establishes that under otherwise identical conditions, the casting with large surface area and small volume will cool more rapidly than a casting with small surface area and a large volume. The relationship can be written as:<sup>[3]</sup>

$$t = B \left( \frac{V}{A} \right)^n,$$

where  $t$  is the solidification time,  $V$  is the volume of the casting,  $A$  is the surface area of the casting that contacts the mold,  $n$  is a constant, and  $B$  is the mold constant. The ratio of the casting's volume to its surface area is the modulus  $M$ :

$$M = \left( \frac{V}{A} \right).$$

The mold constant  $B$  depends on the properties of the metal, such as density, heat capacity, heat of fusion and superheat, and the mold, such as initial temperature, density, thermal conductivity, heat capacity and wall thickness. The S.I. units of the mold constant  $B$  are  $s/m^2$ .<sup>[4]</sup> According to Askeland, the constant  $n$  is usually 2, however Degarmo claims it is between 1.5 and 2.<sup>[5]</sup> The mold constant of Chvorinov's rule,  $B$ , can be calculated using the following formula:

$$B = \left[ \frac{\rho_m L}{(T_m - T_m)} \right]^2 \left[ \frac{\pi}{4k\rho c} \right] \left[ 1 + \left( \frac{c_m \Delta T_m}{L} \right)^2 \right],$$

where

$T_m$  = melting or freezing temperature of the liquid (in kelvins),

$T_m$  = initial temperature of the mold (in kelvins),

$\Delta T_m = T_{cast} - T_m$  = superheat (in kelvins),

$L$  = latent heat of fusion (in  $J \cdot kg^{-1}$ ),

$k$  = thermal conductivity of the mold (in  $W \cdot m^{-1} \cdot K^{-1}$ ),

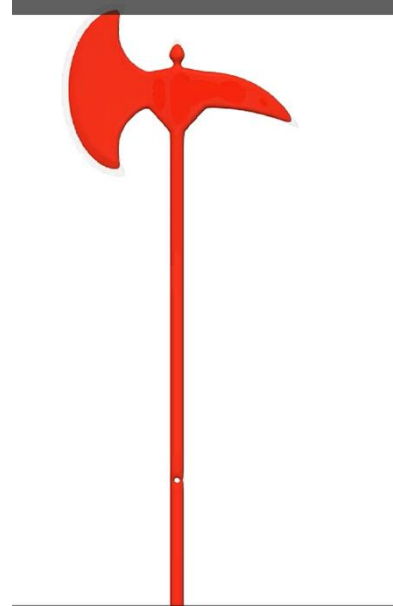
$\rho$  = density of the mold (in  $kg \cdot m^{-3}$ ),

$c$  = specific heat of the mold (in  $J \cdot kg^{-1} \cdot K^{-1}$ ),

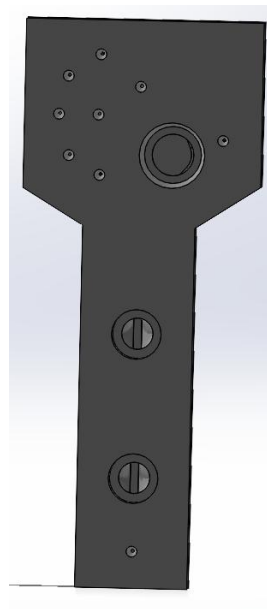
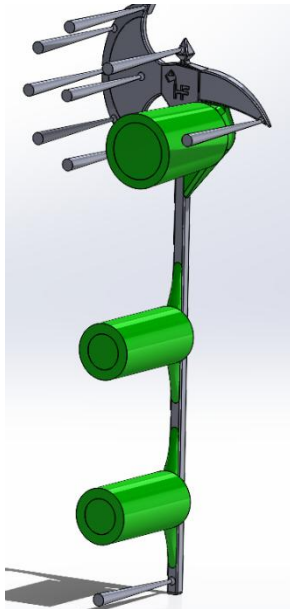
$\rho_m$  = density of the metal (in  $kg \cdot m^{-3}$ ),

$c_m$  = specific heat of the metal (in  $J \cdot kg^{-1} \cdot K^{-1}$ ),

It is most useful in determining if a riser will solidify before the casting, because if the riser solidifies first then defects like shrinkage or porosity can form.<sup>[5][6]</sup>



### Rigging



### Production

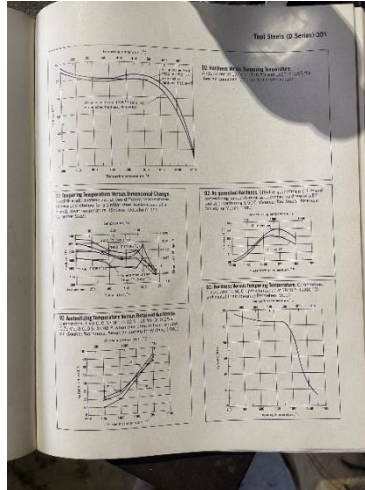
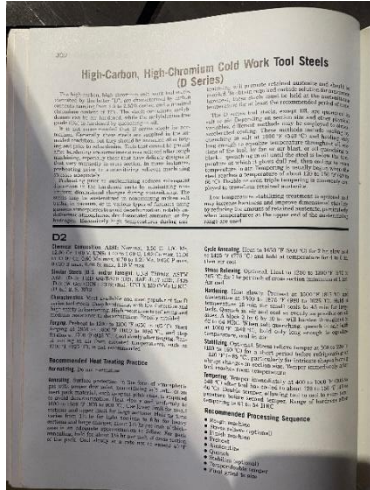
Sand-casting was chosen for making the molds for the axes using a sand printer to produce six axe molds and chills. 3-D sandcasting was chosen because it matches Howell Foundry's specialty/capabilities. Once the molds were pulled off the printer, they were vacuumed and blown out, then coated twice with a wash to prevent sand from burning and sticking to the axes. There was concern that the edge or blade of the axe might be too thin. After the wash dried, the molds were prepped, sealed, and then poured immediately. The following day, the molds were shaken out, and the axes were sorted by their appearance. Unfortunately, all of the axes developed cracks, most of them in the lower part of the blade.



This led to further PT testing to identify invisible cracks in preparation for welding after rough grinding.



Following the welding, the axes were hardened at 1850F for 30 minutes and air quenched using an air hose. Once the axes reached a temperature between 120-150F, they were double tempered for an hour each cycle, first at 900F, then 800F, being allowed to cool to room temperature between the cycles. Both the hardening and tempering processes were created using the graphs and info sheet from below.



By following these procedures, the Bayou Bulldogs were able to achieve a HRC of 57, with the acceptable range for axes being 50-60HRC.

Of the 3 that had been welded, heat treated, and tempered, the axes were ranked on cosmetics, such as the definition of the Louisiana Tech and Howell Foundry logos, while also taking into consideration ridges caused by the molds on the surface of the blade, gouges, and micro-bubbles. The one with the least cosmetic issues would become the competition axe and get priority in completion. Once it was chosen, final grinding was done, with some imperfections being unable to be gotten out. Before the handle was fitted and polishing was done, physical testing was achieved, which consisted of smiting whatever objects such as a metal table, several wooden objects, and a 55-gallon drum that were nearby with the pick and blade. No chipping, abrasions, or deformities were noted following testing. Once testing was complete, the handle was made with a piece of ash wood. After the handle was drilled out, attached to the axe with epoxy, and shaped, the axe was polished using a polishing wheel and compound.

## End Results



This axe weighs 2 pounds, 15 ounces and measures 26 inches long, meeting competition requirements. Its lightweight and compact design makes it ideal for fast, controlled and devastating swings without tiring the user. The shorter handle is essential for mounted combat, allowing greater maneuverability. The thin blade, rather than a thick one, enhances versatility in combat rather than wood chopping. It also features a curved blade and spike, reinforcing its classification as a horseman's axe by enabling a rider to effectively engage enemies while moving. Overall, this axe meets the criteria a) it's a battle axe; and b) is suited for horseback.