# SFSA Cast in Steel 2026 – Horseman's Axe
# Technical Report

## Instituto Tecnológico de Morelia – Hephaestus Smelters


**Team Members:**

Ceylin Fernández Salvador
Marlen Santos Rodríguez
Germán Cruz Villanueva
José Gerardo Granados Sánchez

**Advisor(s) Name:**
*Dra. Nereyda Alcantar Mondragón*

**Foundry Partner:**
*Acerlan Matrix Metals S.A. de C.V*

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## Introduction

The Cast in Steel 2026 competition aims to encourage students to further their knowledge of casting processes and the application of advanced manufacturing technologies. This initiative allowed us to participate actively, applying our technical expertise and developing practical skills in the fabrication of the iconic "Horseman's Axe" using modern manufacturing techniques. For this project, we developed an axe based on original concepts, drawing inspiration from historical models such as the "Francisca" (Battle-Axe of the Franks), which stands out for its historical significance and the complexity of its design and manufacture. The development of this weapon was a significant technical challenge that required the application of advanced steel casting principles, as well as specialized techniques in the design and finishing of the final product. The design features attractive and complex geometries optimized to achieve an excellent performance-to-strength ratio. Furthermore, the selection of 8630H alloy and the definition of heat treatment parameters—based on rigorous technical analyses—ensured the product's functionality. Finally, the implementation of sophisticated quality control techniques ensured that the final product met the specified requirements.

## Historical Background

The horseman's axe has its origins in the Francisca, a weapon that appeared in northern Europe with the arrival of the Franks around the 5th century. These warriors, who formed the Germanic confederation from which empires such as Charlemagne's would emerge, crafted these axes with a heavy iron head and a short wooden handle. Originally, they were not only close-combat weapons but also throwing weapons designed to be hurled in volleys before the initial clash, with the aim of shattering enemy shields and disrupting their ranks. Their unique design meant that even if they didn't strike directly with the blade, the projectile would bounce unpredictably off the ground, making it difficult for defenders to block and causing chaos in the enemy ranks [1].

Over the centuries, the design evolved under the influence of other Germanic and Scandinavian peoples, giving rise to variants such as the Viking bearded axe, whose makers refined the manufacturing technique by forging steel edges onto iron heads to achieve superior cutting power. However, the concept of a specialized axe for cavalry became more technically sophisticated toward the end of the Middle Ages and the beginning of the Renaissance, mainly due to improvements in plate armor. As body armor became nearly impenetrable by traditional swords, elite knights began to prefer impact weapons. A prime example of this transition is the Spanish horseman's axe from around 1540, whose original model is housed in the Royal Armory in Madrid [1,2].

These Renaissance weapons were specifically designed to be used while mounted on horseback; they measured approximately 24 inches in total length and featured practical details such as holes in the handle to fit leather straps or belt hooks, which made them easier to carry while riding. Its functionality on the battlefield was extremely versatile;

the curved blade was used to inflict lethal strikes from the height of the saddle, and the long rear spike became an essential tool for piercing even the toughest metal armor [1,2].

## 1. Material selection

For this project, AISI 8630 alloy steel was selected, which is a low-carbon alloy containing Ni, Cr, and Mo. It is known for its excellent toughness, hardenability, and good weldability. The chemical composition of the used alloy is shown in **Table 1**. It has been shown that Ni increases toughness, while Cr and Mo improve high-temperature resistance [3-5]. The presence of alloying elements promotes a balanced distribution of ferrite, pearlite, and martensite or bainite, allowing the axe to efficiently absorb the impacts to which it will be subjected, while ensuring that the blade performs adequately.

**Table 1. Chemical composition of the selected steel**

| Element | C | Si | Mn | P | S | Cr | Mo | Ni | Al |
|---|---|---|---|---|---|---|---|---|---|
| (%wt) | 0.3 | 0.5 | 0.87 | 0.016 | 0.014 | 0.5 | 0.214 | 0.54 | 0.049 |

## 2. Axe Design

The proposed design was modeled in SolidWorks and is inspired by the typical geometry of a double-edged medieval axe. From this sketch, an asymmetrical model was proposed featuring an effective cutting edge of 204 mm in length at one end and a 105 mm-long point at the other **(Fig. 1a).** The design thickness was set at 12.5 mm, which is sufficiently robust to prevent cracking. In addition, the draft angles were set at 3° from the vertical line relative to the parting line, and the edges were rounded to reduce the tendency to generate cold spots [6] .

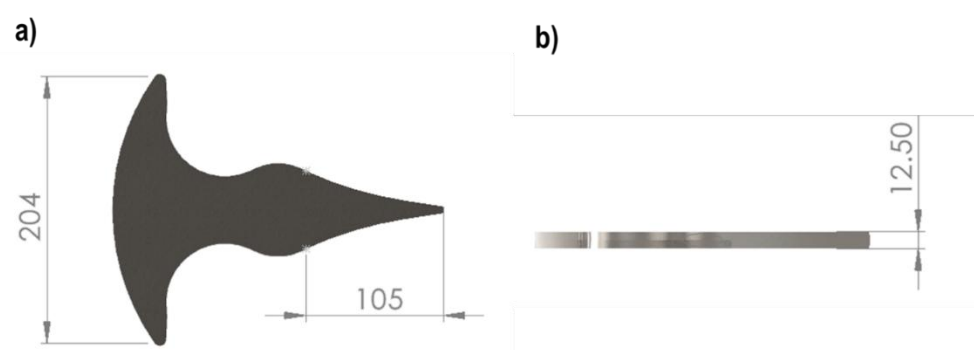



**Figura 1**. Dimensions of the axe blade: a) front view, b) side view

The initial weight of the axe blade was estimated at 1,634 g, which substantially exceeds the established maximum weight. Consequently, a pair of machining operations were proposed to reduce the total weight. The first operation consists of a rough cut along a diagonal path (**Fig. 2a**), reducing the total weight by 32% (1,121 g). The second procedure involves shaping two tapered edges, as shown in **Figure 2b,** resulting in a reduction of more than 51% and achieving an estimated weight of 809.36 grams. This ensures compliance with the established weight requirements without compromising the axe's integrity. In addition, an asymmetrical, rustic handle with cross-sectional changes was designed. To improve one-handed handling, the lower section was widened. The dimensions of the proposed handle are shown in **Figure 2c.**

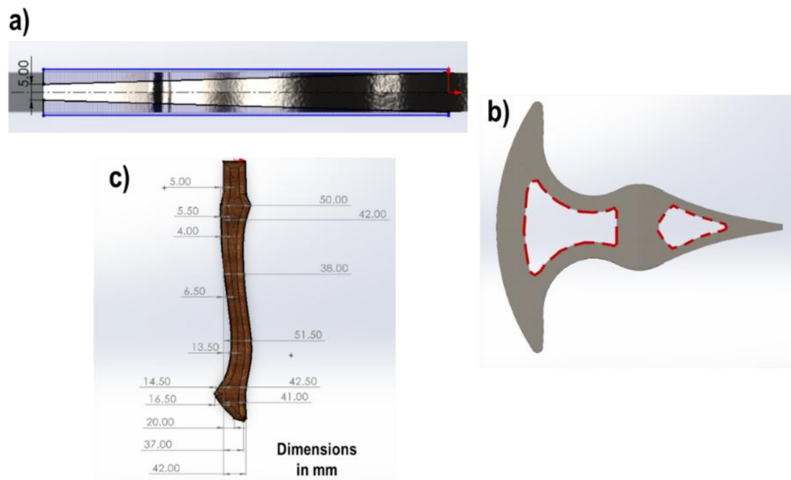



**Figura 2.** Sequence of machining operations to reduce the weight of the axe blade: a) Cross machining, b) Pocket machining, c) Dimensions of the proposed handle.

## 3. Casting Process

Based on the CAD model, the risers, feed channels, and vents were designed and dimensioned. Defect prediction and solidification times were calculated using Magma software (**Fig. 3a–b**). The model was fabricated using FDM with PLA as printing material **(Fig. 3c**). Next, the casting process was carried out using silica sand. It is important to note that the casting process was very simple, since there was no need to use cores and the geometries were properly designed. Finally, the feed channels and sprues were cut, and the axe head underwent a tempering heat treatment, the effect of which would later be evidenced in the microstructure and mechanical properties. There is a significant difference between the final axe and the images related to the casting process (**Fig. 3**). This is because the original design featured a double-edged blade; however, upon realizing that this geometry did not fulfill the contest requirements, the necessary modifications were made, resulting in the design presented in section 1.

**Figure 3.** Steps in the casting process: a) Setup used in the SolidCast simulation, b) 3D-printed model, c) axe blade in as-cast condition.

## 4. Blade machining and handle fabrication

After performing a tempering heat treatment to homogenize the microstructure and thereby improve machinability, a CNC milling machine was used to carry out the machining sequences described in Section 2 (**Figures 4a–b**). Cedar wood was chosen for the handle due to its many benefits. Cedar is known for its excellent strength-to-weight ratio, ideal for making long handles. Because of its porous structure, it absorbs shocks and vibrations, substantially improving ergonomics and reducing strain and fatigue in the hand of the user [7,8]. In addition, cedar is easy to work with, allowing for the creation of complex shapes without splintering [9]. Figure 4c shows the semi-finished handle assembled to the axe blade.

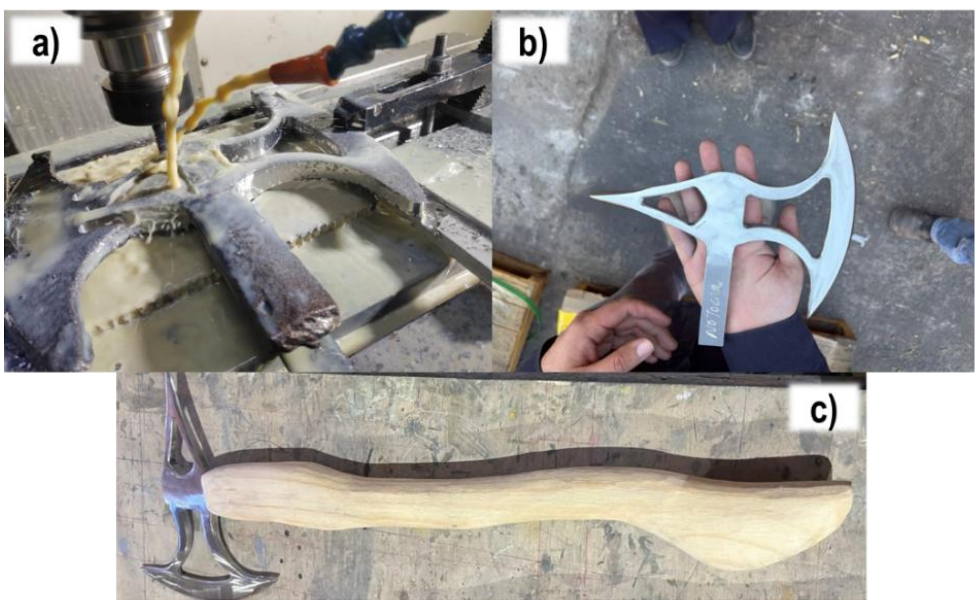


**Figure 4.** Steps in machining the blade and manufacturing the handle: a) 2.5-axis blade machining; b) machined blade with a preliminary edge; c) preliminary shape of the handle assembled to the blade.

## 5. Mechanical and microstructural characterization

To promote grain refinement and achieve a homogeneous equiaxed microstructure, while mitigating the solute segregation and residual stresses inherent to the as-cast axe. The piece was subjected to a normalizing at 930°C. A soaking period of 4 hours was maintained to ensure full homogenization. The heat treatment parameters were defined through thermodynamic simulation of the Time-Temperature-Transformation (TTT) diagram using JMatPro software, as shown in Figure 5.

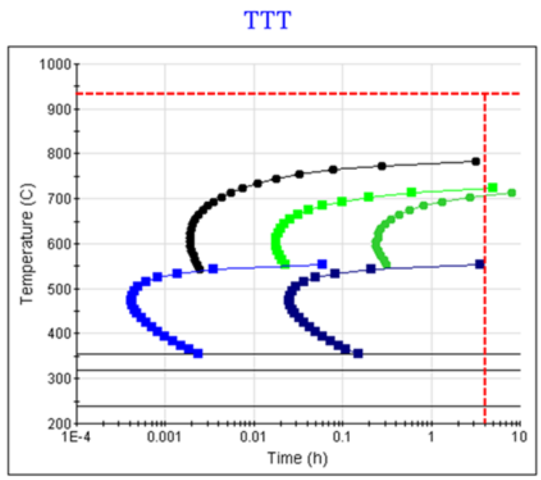



**Figure 5.** TTT diagram of the selected alloy for axe blade (8630H).

A sample was cut from the heat-treated material, and conventional metallographic preparation—including roughing with SiC abrasive paper, polishing with 3-µm diamond paste, and etching with 2% nital—revealed the microstructure, which consists of ferrite (bright areas) and represents 50% of the microstructure, as shown in **Figure 6a**. Fine pearlite (dark area) and coarse pearlite (dark brown area) are present, forming a necklace around ferrite grains and fine pearlite (**Fig. 6b**)

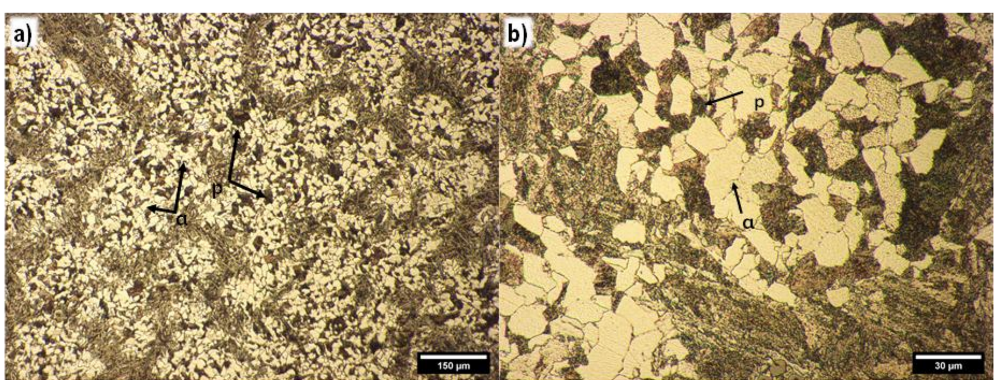
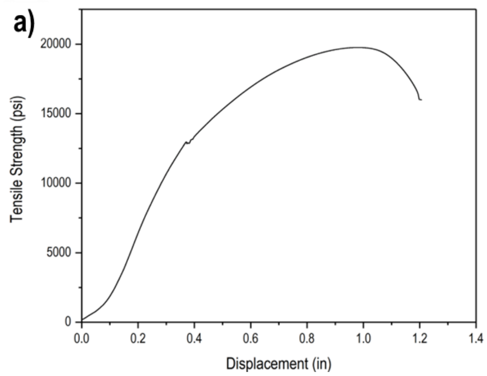



**Figure 6.** Metallographic examinations of 8630H steel normalized at 930°C for 4 hours and etched with 2% nital for 3 seconds

Tensile tests were conducted in accordance with ASTM-24. From the stress-strain diagram (**Fig. 7a**), an elastic limit of 65,687.8 psi and a maximum stress of 100,623 psi were achieved, with an elongation of 29%. The remaining data obtained from the curve are reported in **Figure 7b.** The mechanical characterization was complemented with Charpy tests at –21°C and microhardness testing. The results show that heat-treated steel is ideal for conditions requiring good strength and toughness.




**b)**

| | |
|---|---|
| Yield Strength 0.2% (psi) | 65687.8 |
| Tensile Strength (psi) | 100623 |
| Elongation in 2 inch gage length (%) | 29 |
| Reduction of area (%) | 51 |
| Microhardness (HV) | 197 |
| Charpy impact energy in -20° C(J) | 95 |

**Figure 7.** Mechanical characterization of the used steel; a) stress-strain diagram, b) data obtained from tensile, microhardness, and impact (Charpy) tests

## 6. Blade sharpening and handle detailing

The blade and pick were sharpened to prepare for testing. To add detail to the handle, decorative patterns were carved using a pneumatic hand tool. Additionally, an aluminum stamp was CNC-machined to hot-stamp the sponsoring company's logo onto the lower section of the handle (**Fig. 8 a–c**)

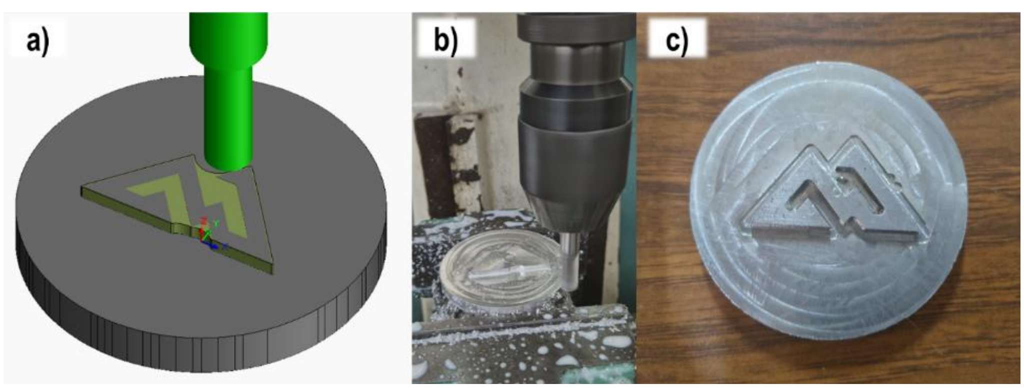



**Figure 8.** Stamp manufacturing process: a) Machining simulation in SolidWorks CAM, b) Stamp machining, c) Final product.

## 7. Final Results

**Figure 9.** Final product with a total weight of 1 kg.

## Acknowledgments

We would like to express our deepest gratitude to the Steel Founders' Society of America for organizing this competition, which provides students an invaluable opportunity to develop specialized technical skills in the steel casting process. This initiative has promoted the strengthening of essential soft skills, such as collaborative work, leadership, and the ability to solve complex problems in a technical environment.

We extend our gratitude to Acerlan Matrix Metals for their trust and essential support as a project sponsor. Our direct collaboration with the industrial sector allowed us to participate in critical metallurgical decision-making for the axe's manufacture, successfully overcoming the technical challenges inherent in the process. In particular, we thank Lourdes Yareth Herrera Chávez and Ivan Uriel Huerta Moran for their commitment, effort, and constant guidance during the casting process.

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Last but not least, we would like to thank our alma mater, the Instituto Tecnológico de Morelia, for laying the foundations of our professional growth and for inspiring and encouraging us to participate in major international events such as this one.

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