SFSA Cast in Steel 2025 - George Washington´s Sword
Technical Report

Instituto Tecnológico de Morelia - Alloy Avengers

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Introduction

The Cast in Steel 2025 competition aims to encourage us as students to delve deeper into the steel casting process and the application of advanced technologies in manufacturing. This initiative allowed us to participate, apply our technical knowledge and develop practical skills in the elaboration of George Washington's emblematic sword by implementing modern manufacturing techniques.

We developed a replica of the Alte Presentation Broadsword, because it stands out for its historical significance and its complexity in design and manufacture.

The development of this replica represented a technical challenge that required the application of advanced manufacturing principles of steel casting, as well as specialized techniques in design and finishing of the final product. This sword not only resembles the original, but also meets the appropriate mechanical properties to resist real efforts, the computer aided design was done in SolidWorks where we were able to model the sword and optimize its geometry. The choice of alloy 8630 and the heat treatment parameters were based on technical analysis to ensure the functionality of the final product. The application of advanced quality control techniques ensured that the result met the expected historical and technical standards.
This report details the manufacturing processes, technologies employed and challenges overcome during the development of Alte Presentation Broadsword.

Historical Background

The Alte Presentation Broadsword is a sword of symbolic and historical value that reflects the impact that George Washington had not only in the United States, but throughout the world. This piece was made by Theophilus Alte, a master swordsmith originally from Solingen, Prussia, who was recognized for his excellent work in the manufacture of swords that stood out for their quality. During the 17th and 18th centuries, Solingen swords were in high demand for their precision, hardness and resistance, making this city a world reference in the steel industry.

The Alte Presentation Broadsword was created as a commemorative gift for George Washington. The sword stands out for its elegance, design and deep symbolic meaning. It was a token of respect and admiration for Washington, who had led the American colonies during the War of Independence and later became the first president of the United States. His image as a leader of integrity transcended borders, earning the admiration of international figures such as Theophilus Alte.

In the letter that was sent with the sword, Alte mentions that his son, Daniel Alte, had personally taken the gift to Washington in the hope that the president, whom he considered a just and protective man, would provide him with security and support in the United States. Alte described Washington as the only man who acted selflessly for the happiness of his country. However, Daniel Alte's fate remains unknown, which has plunged this story into mystery and tragedy. The sword is a piece with detailed engravings that reflect the craftsmanship of the period. Its design incorporates ornamental elements that symbolize loyalty, honor and sacrifice. The balance between the weapon's functionality and its aesthetic value demonstrates the high technical level achieved by the craftsmen of Solingen.

The legacy of the Alte Presentation Broadsword transcends the material; it represents the deep admiration that George Washington inspired as a historical figure. This sword has become a tangible testament to the respect leaders and citizens around the world felt for the man who led a nation to independence and laid the foundation for its democracy. The history of this sword, marked by uncertainty about the fate of Daniel Alte, is an emotional component that reinforces its historical value, consolidating it as one of the most representative symbolic pieces of international respect for the first president of the United States.

1. Material Selection

For this Project, steel 8630 was selected, a low-alloy steel that belongs to the family of alloy steels according to ASTM A958. Steel 8630 belongs to the 86XX series, which indicates that it is a steel alloyed with nickel (Ni), chromium (Cr) and molybdenum (Mo). This combination significantly improves its mechanical strength, hardness and ability to withstand dynamic loads. The detailed chemical composition of this alloy can be seen in Table 1.

AISI 8630 steel is widely used in industry due to its excellent strength to toughness ratio, which makes it an ideal material for components subjected to considerable mechanical stress. Its balance between ductility and toughness enables it to withstand impacts without fracturing easily. In addition, this alloy has a good response to case hardening, which allows it to increase surface hardness without sacrificing toughness.

Table 1. Chemical composition of the steel used for the blade of the sword									
Element	C	Si	Mn	P	S	Cr	Mo	Ni	Al
(%wt)	0.301	0.514	0.847	0.0161	0.0120	0.694	0.232	0.572	0.0322

2. Computer Aided Design (CAD)

The design of the sword was carried out using SolidWorks software, employing surface modeling tools that allowed generating the blade profile with a variable cross section with a double taper as the original model. The variation of such section was achieved with a sweep of two profiles whose dimensions and shape are shown in Fig. 1(b-c). The design was made from the top plane taking into account the position of the mold parting line. The sword blade was designed to have an overall length of 90 cm and a maximum width of 4.5 cm. The dimensions of the original model were adjusted to the requirements of the competition and the shape of the handle was modified from the original design to improve the maneuverability of the sword. Further details and dimensions of the handle used are shown in Figure 2. The design was carried out under the general design guidelines for casting, such as verifying that the surfaces perpendicular to the parting line have demolding angles of 3°, avoiding orthogonal geometries to avoid the generation of cold spots and therefore cracking, respecting minimum wall thicknesses, etc [1].

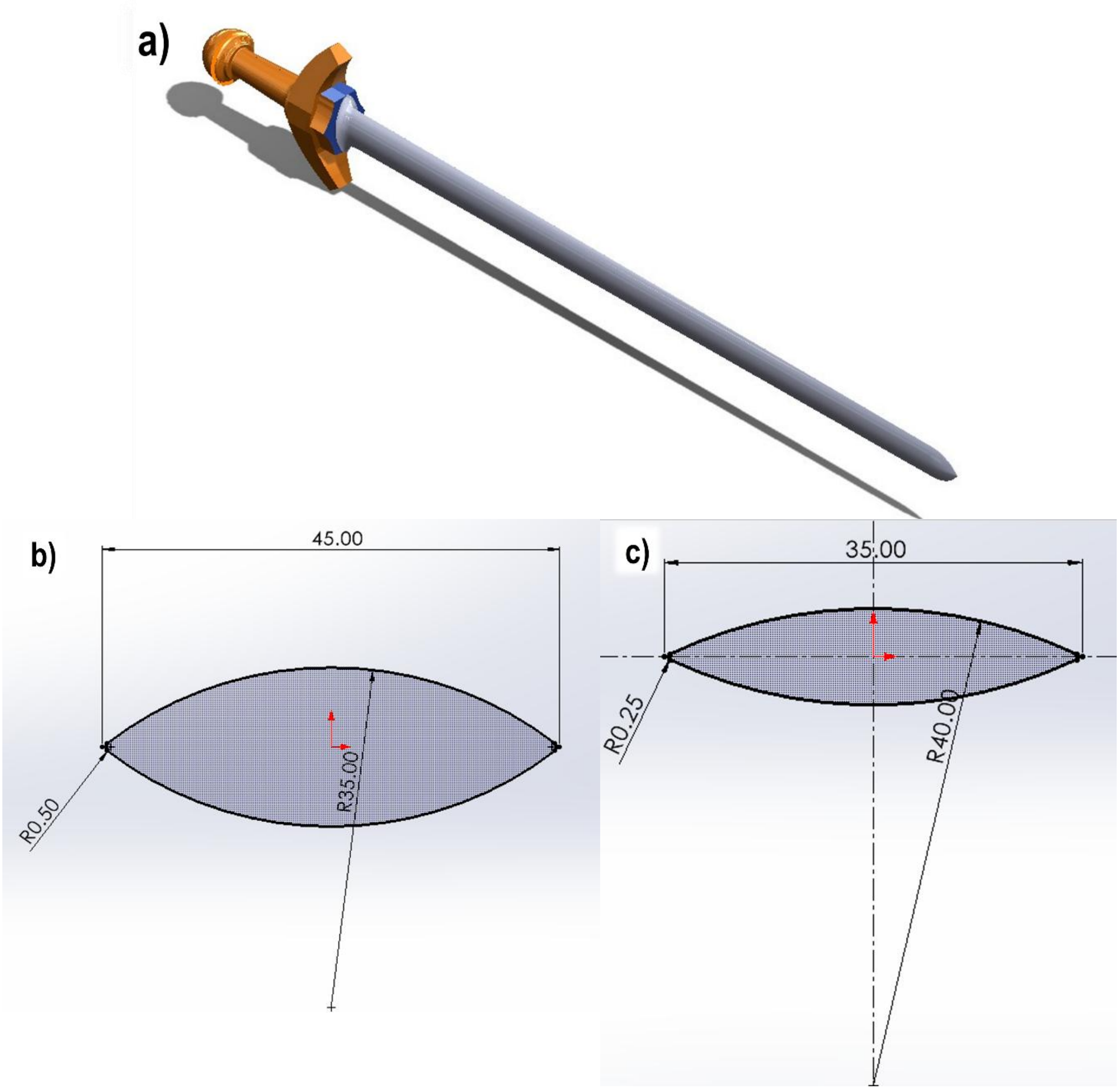

Figure 1. SolidWorks® modeling of the sword; a) isometric view of the sword and handle, b) larger profile for the blade sweep, c) smaller profile for the blade sweep.

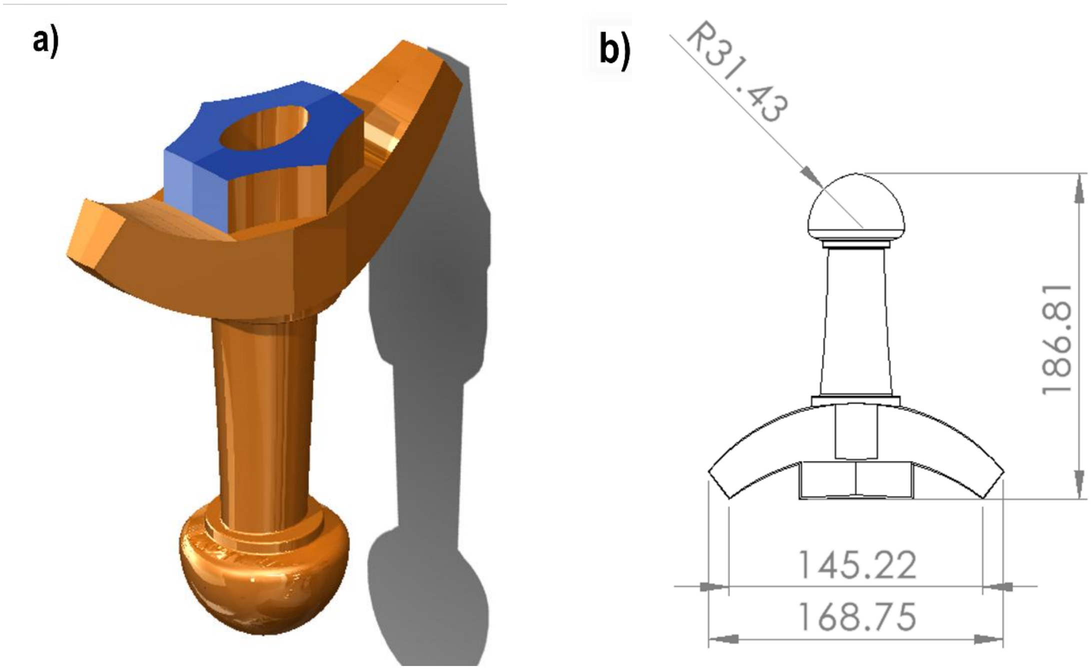

Figure 2. Details and dimensions of the designed handle; a) front view of the handle, b) representative dimensions of the handle.

3. Casting simulation

MAGMASOFT® software was used to ensure correct mold feeding and minimize defects such as porosities, inclusions and shrinkage. This tool allows predicting the fluid dynamics of the liquid steel during casting and quantifying solidification defects. The sprues, feeding systems and risers were designed taking into account the recommendations suggested by Campbell for sand casting [2]. Based on the results obtained, the design of the aforementioned geometries was optimized to have as few surface and volumetric defects as possible. The casting and solidification time predicted by the software was calculated in 6 min and 2.5s. Based on the modifications made, it can be seen that the blade part of the sword will be free of pores and that these will be concentrated in sections of the feed system that will be removed later. In this way it was verified that the design is now suitable for manufacturing the models and proceeding to the molding and casting stages.

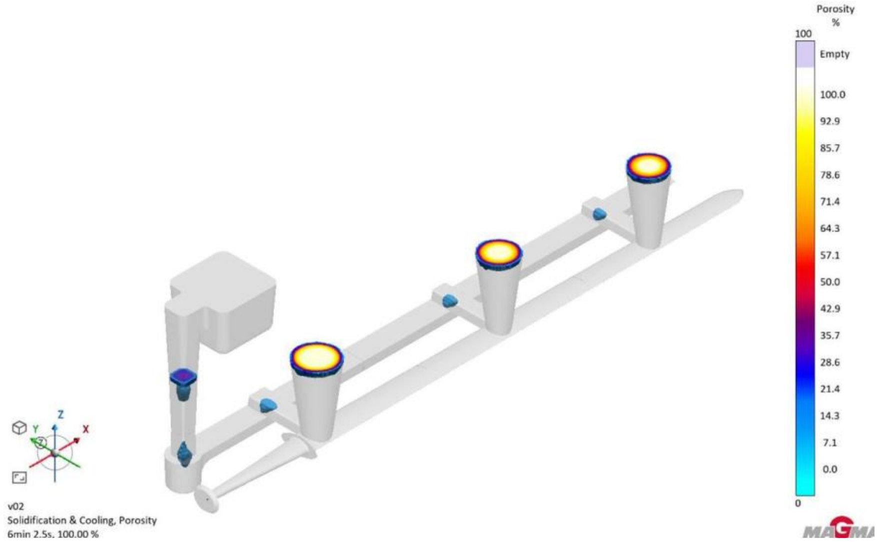

Figure 3. Simulation of the casting in MAGMASOFT® showing that the sword blade will be free of porosities.

4.- Model 3D-Printing

The models used were manufactured by additive manufacturing (3D printing), using the Fused Deposition Material (FDM) technique. This technology creates 3D parts by continuously depositing layers of material by heating and extruding filament, which is typically polymeric. It is an effective process for rapid prototyping of parts from conceptual models in short periods of time, generating a substantial decrease in manufacturing costs. [3], [4]. Polylactic Acid (PLA) was used for printing the models due to its high printability, dimensional stability and low susceptibility to shrinkage or interlayer adhesion phenomena. The fabrication parameters were set in Ultimaker Cura software and the models were printed on a Creality K1 Max printer. The model of the sword was segmented into 4 parts and then joined to form the corresponding cavity in the mold (Figure 4). Figure 5 shows the models to form the cavities of the feed channels, risers and blade of the sword placed for the next stage of molding.

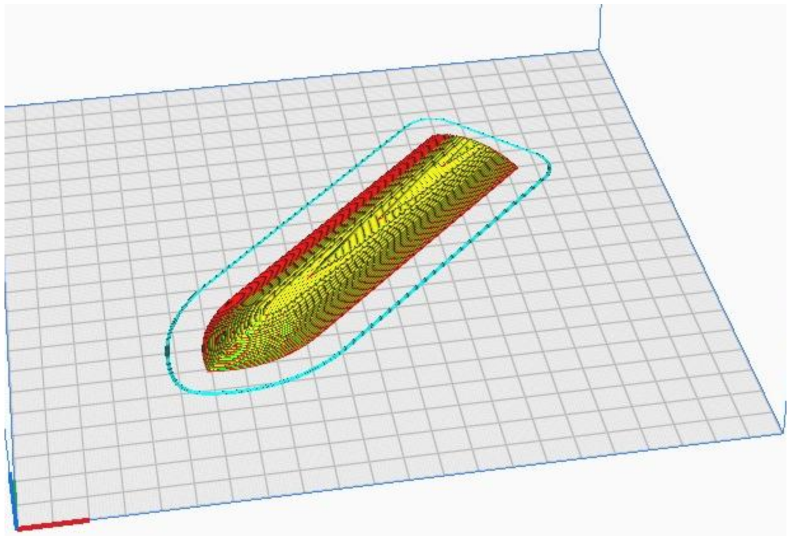

Figure 4. Visualization in Ultimaker Cura software of a section of the sword blade model.

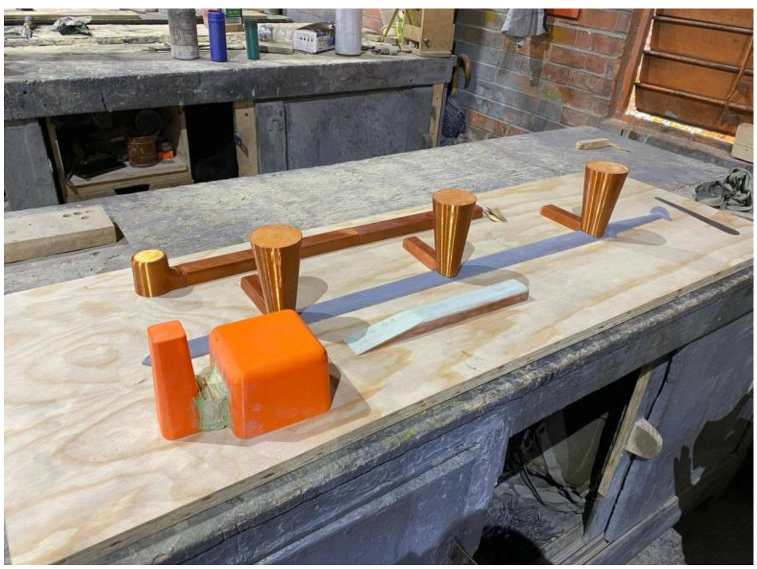

Figure 5. Arrangement of the printed models for the feeding system, feeders, sprue and sword blade, for the subsequent molding stage.

5. Molding and casting

Once the models were arranged in the two sections with respect to the parting line, the demolding powder was placed and the sand was tamped. It should be noted that the molding stage was carried out in a semi-automated manner. Silica sand (SiO_2) in an 80/20 ratio with recycled sand was used to manufacture the mold. Further details of the two sections of the mold can be seen in Figure 6. The melting of the material was carried out in an electric arc furnace with a capacity of 7 tons. The chemical composition was constantly monitored to verify that the alloying elements were within the established limits.

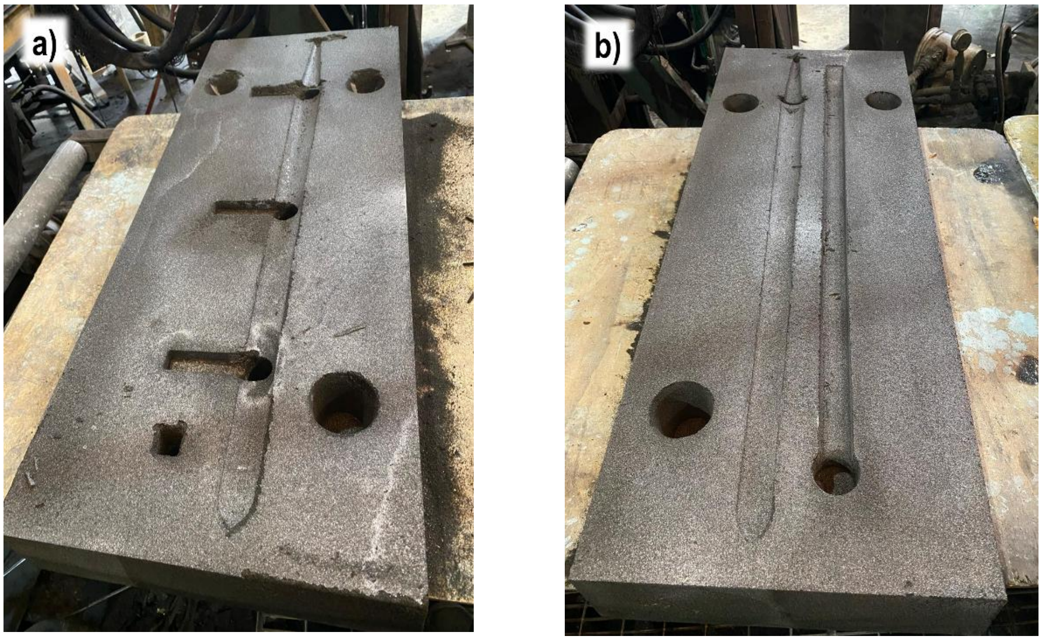

Figure 6. Mold for obtaining the sword blade; a) upper part, b) lower part.

6. Heat Treatments

Because the sword blade was not thermo-mechanically treated (or forged), casting structures were still present in the blade, making it highly susceptible to performance failures. For this purpose, it was given a normalized heat treatment at 930°C for 3 hrs, significantly improving its ductility and toughness. As a complement to the normalized treatment, a water quenching was carried out so that it would acquire the necessary mechanical resistance for the performance tests. And finally, a tempering treatment was applied at 650°C for 4 hrs, in order to modify the morphology of the martensite generated during hardening and thus substantially increase impact toughness. Figure 8 shows the CCT and TTT diagrams (obtained with JMatPro software), which were used as an auxiliary for the design of the heat treatments. Figure 8 shows the furnace used for the treatments together with the quenching vat.

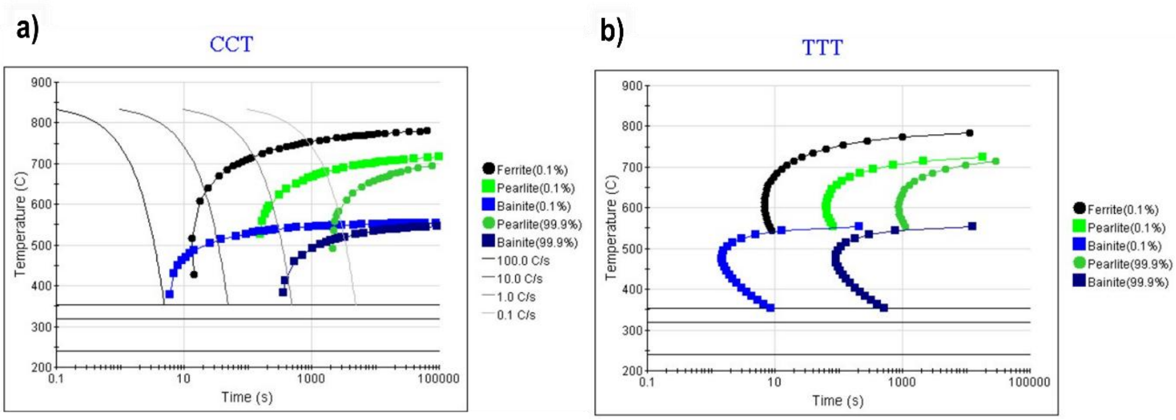

Figure 7. Auxiliary diagrams for the design of heat treatments based on the chemical composition of AISI 8630; a) CCT, b) TTT.

Figure 8. Furnace where the heating for the heat treatments was carried out together with the instrumented quenching vat.

7. Mechanical and metallographic characterization

7.1. Tension test

With the steel in normalized, quenched and tempered condition, a round specimen was machined for a tensile test under ASTM E8 [5] specifications (Figure 9(a)). Destructive testing was performed on a SHIMADZU universal testing machine with a capacity of 50 tons (Figure 9(b)). The change in specimen length during elastic deformation was quantified with a mechanical extensometer. A yield strength (YS) of 121.6 ksi, an ultimate tensile strength (UTS) of 139.4 ksi and a maximum elongation of 0.63 in (16 mm) were reported. Figure 10 shows the stress-strain curve generated during the test.

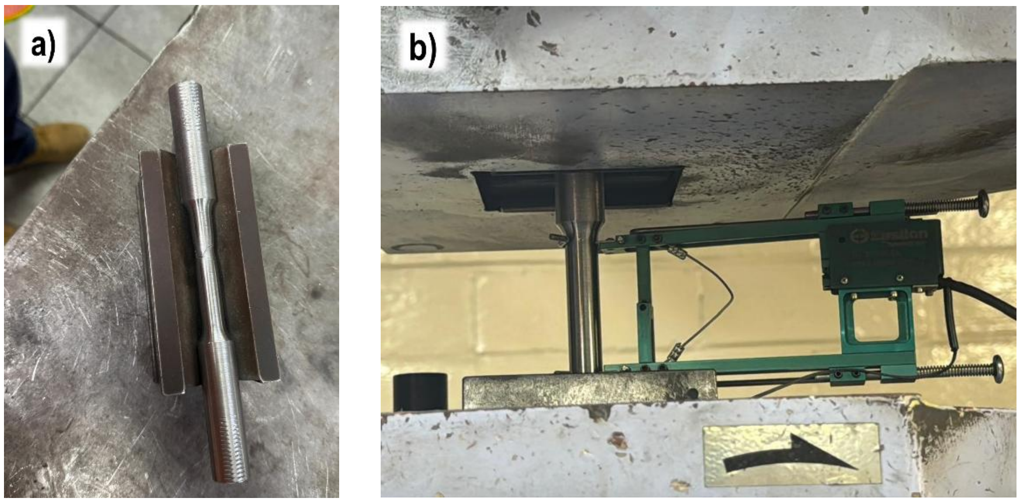

Figure 9. Tensile test; a) specimen manufactured according to ASTM E8 standard, b) Tensile test with instrumented mechanical extensometer to measure strain.

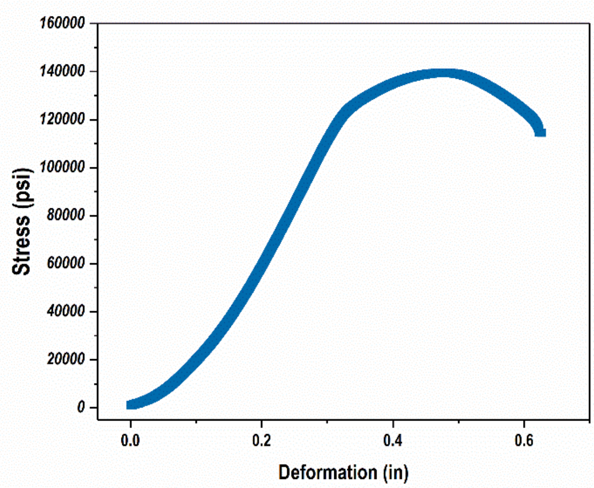

Figure 10. Stress-strain diagram of the tensile test performed on AISI 8630 in normalized, quenched and tempered condition.

7.2. Impact test

Three specimens were machined for the Charpy impact test of steel in normalized, quenched and tempered condition, according to ASTM E23 specifications [6]. (Fig. 11(a)). The tests were conducted in a 300 J capacity (Fig. 11(b)). Prior to the tests, the samples were conditioned at a temperature of -29°C for at least 10 min in a controlled cooling chamber to evaluate the behavior of the steel at low temperatures. Three tests were performed to verify the repeatability of the results obtained, quantifying an average absorbed energy of 50 ± 3.6 J. The results of each test are shown in Table 2.

Tabla 2. Resultados de las pruebas de impacto		
Specimen	**Prueba Charpy V Notch a °C**	**Absorbed Energy (J)**
1	-29 °C	54
2	-29°C	47
3	-29°C	49

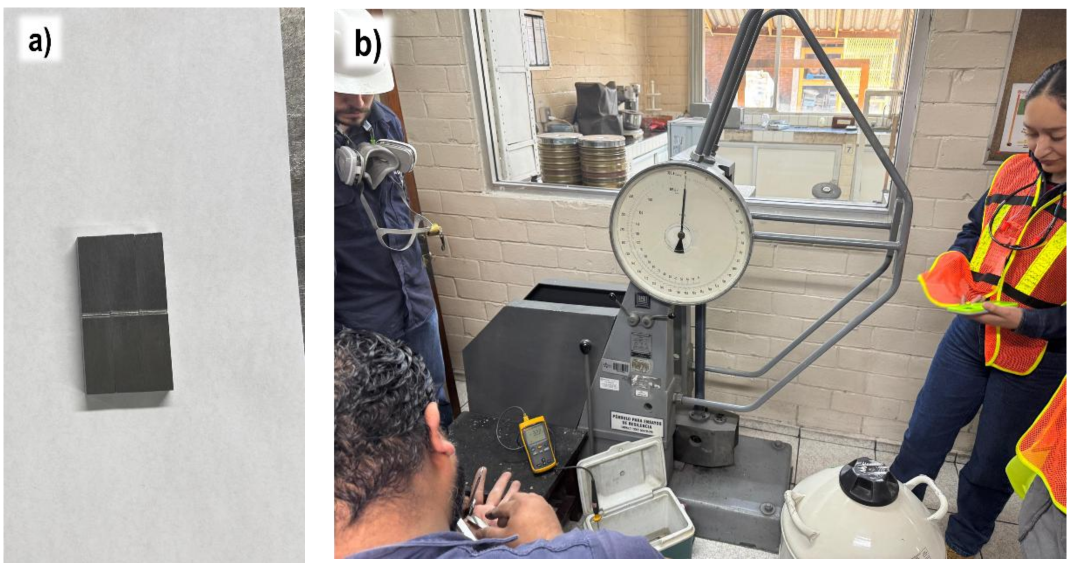

Figure 11. Charpy Impact Test; a) specimens manufactured under ASTM E23 specifications, b) impact test with liquid nitrogen induced cooling.

7.3. Metallographic characterization

From the impact specimens, specimens were extracted for the metallographic characterization of the material after applying the heat treatments. For this purpose, mechanical roughing was performed with SiC sandpaper with a grain size ranging from 80 to 2000 and then the specimens were polished with 0.03 μm alumina. Finally, they were chemically attacked by immersion with Nital-3 reagent. The metallographic and reagent preparation was carried out according to ASTM E407 specifications [7].

The metallographic analysis (Fig. 12) showed a large amount of martensite due to the tempering applied, this microconstituent is characterized by having a darker color. Its morphology does not have such a pronounced acicular aspect due to the tempering applied. Additionally, islands of ferrite (lighter in color) can be seen and the grain size is quite small.

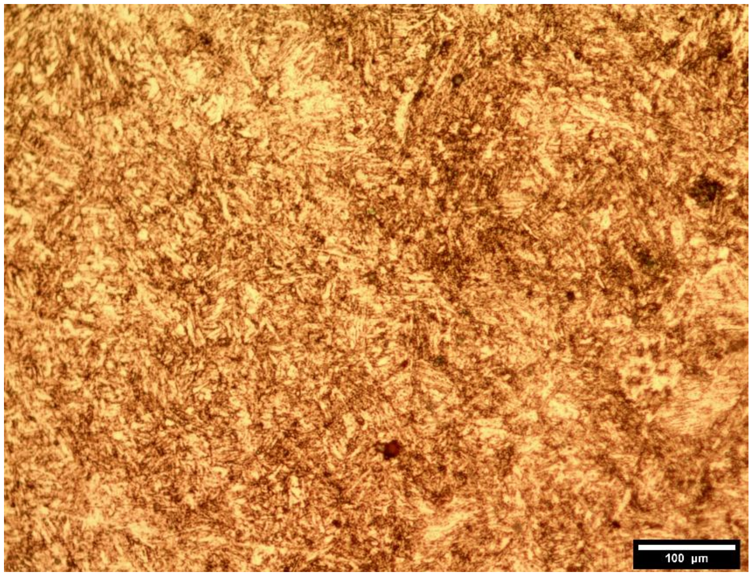

Figure 12. Metallography of AISI 8630 steel used after application of heat treatments.

8. Handle fabrication and final details

The handle was handcrafted from pine wood (Fig. 13(a)). It was varnished and an ornamental leather detail was added. The sword blade was mechanically roughened with a hand polisher and coarse grinding discs (Fig. 13(b)). Subsequently, sanding discs were used to improve the texture and surface finish. Then, the blade was manually sharpened with an emery and a sharpening stone. Finally, the blade was given a fine polish and a special box was made for shipping (Fig. 13(c)).

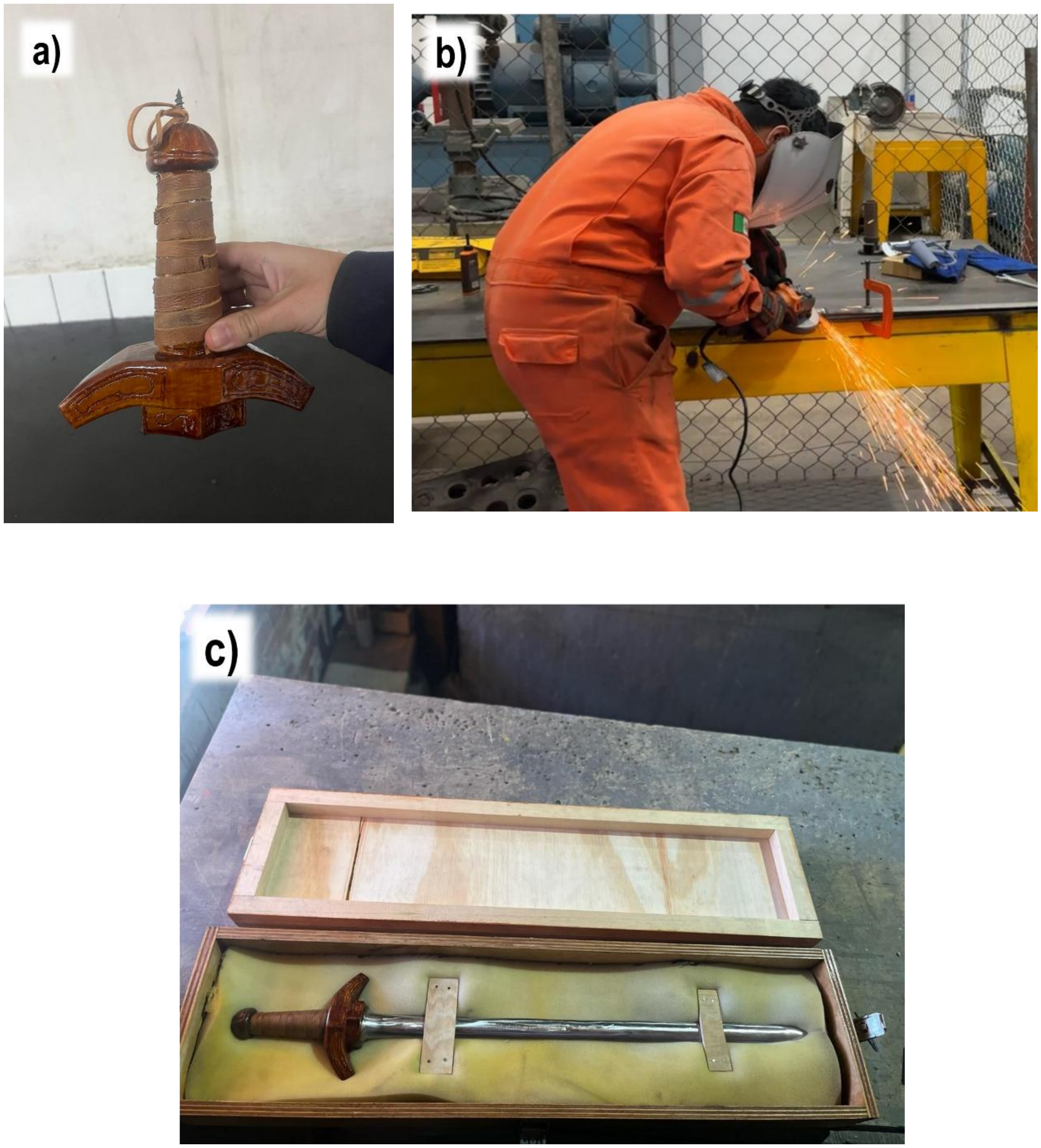

Figure 13. Final operations of the sword; a) fabrication of the handle, b) grinding and polishing operations, c) assembly of handle with blade and fabrication of box for shipping.

Acknowledgments

We would like to thank the **Steel Founders' Society of America** for organizing this type of competition, which provides us, as students, with the opportunity to develop skills in the casting process. Thanks to this initiative, we were able to collaborate directly with a company in the sector, making key metallurgical decisions in the fabrication of our sword. This project not only allowed us to apply our technical knowledge but also strengthened our teamwork, problem-solving, and leadership skills.

We extend our thanks to **Acerlan Matrix Metals** for trusting us and for their invaluable support as sponsors, which made the realization of this project possible. In particular, we thank **Yareth Herrera** and **Iván Huerta** for their support throughout this process, as well as for their effort and commitment to making the casting of the sword a success. Their dedication was fundamental in overcoming the technical challenges we faced.

We thank **Dr. Francisco Reyes Calderón** for his guidance and support in making metallurgical decisions, as well as for his direction throughout the entire work related to the sword's fabrication. His experience and guidance were essential in achieving a successful result that fills us with pride. His commitment to the academic and professional development of his students has been key to our growth.

We also thank **Dr. Monserrat Sofía López Cornejo** for her constant support to students. Her valuable help in securing a sponsoring company was crucial for our participation in this edition of the competition.

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