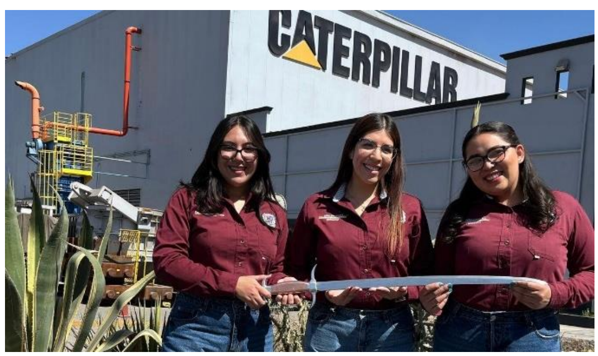
SFSA Cast In Steel 2025 – George Washington´s Sword

Technical Report

Instituto tecnológico de Saltillo – Liberty Blade



Team members:

- **Obdulia Moreno**
- **Ximena Villasana**
- **Joana Barocio**

Advisor (s) Name:

- **Dr. Efraín Almanza Casas**
- **Ing. Jesús Zamora**

Foundry Partner:

CATERPILLAR Ramos Arizpe

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Summary

This Project consists of the fabrication of a sword insipred by George Washington and the swords he used to wield. This Project is carried out annually with the goal of allowing students to again experience in casting, learn from companies, and acquire practice and knowledge abput process desing.

This sword was designed and crafted in collaboration with Caterpillar Ramos Arizpe, who served as a fundamental guide in the development of this Project. The system used for the reproduction of the sword was the cold box method. For this process, the desing, simulation, and adjusments of a tooling system were carried out for the production and casting of the sword Blade,which was made with 1076 steel.

This document outlines both the technical development of the process and the problems encoutered, alon g with the technical that had to be made to address these issues. Lastly, it presents the conclusions drawn from the development of this Project.

Introduction

The Steel Founders' Society of America (SFSA) has developed this contest with the purpose of encouraging students to deepen their knowledge about the manufacture of steel products through the casting process, also promoting the application of advanced technologies in manufacturing. In this context, this report documents the design, manufacture and analysis of a steel sword inspired by George Washington, a symbol of leadership and determination in the history of the United States.

The development of this piece required the integration of knowledge in casting, material selection and metallurgical processes to ensure both aesthetic fidelity and adequate mechanical properties. Throughout the report, the design criteria, the methodology used in the foundry, the heat treatments applied and the evaluation of the final properties of the steel obtained will be detailed.

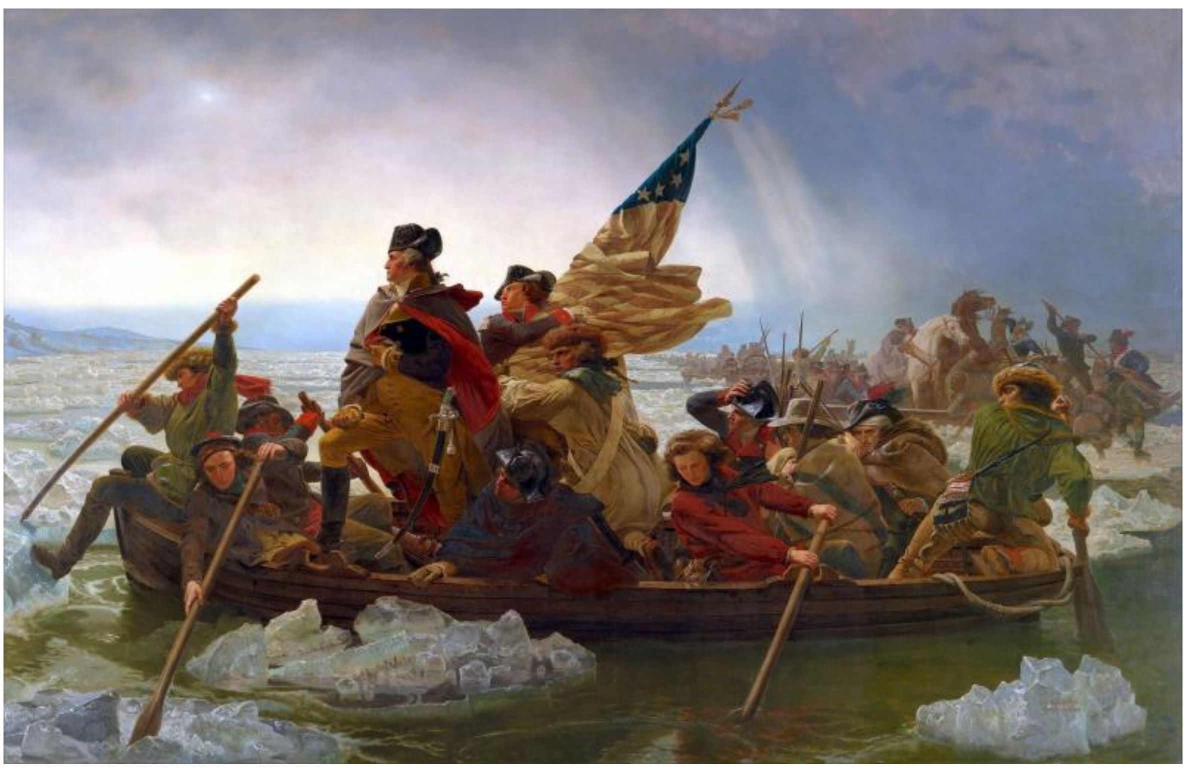
This project not only allowed the application of theoretical knowledge in a practical challenge, but also represented an opportunity to innovate in the manufacturing of steel components, aligning with the objectives of the competition promoted by the SFSA.

Historical context

George Washington, as commander-in-chief of the Continental Army during the American Revolutionary War (1775-1783) and first president of the United States (1789-1797), is an iconic figure whose image is closely linked to leadership and bravery. Among the most emblematic objects associated with him is his sword, a symbol of his military role and his commitment to the revolutionary cause.

For this project, we decided to base it on one of the two swords that General George Washington used during the American War of Independence: the lion's head cutlass. This was his trusted weapon in the first confrontations, and Washington felt great pride in it, since it was forged in the United States by a Philadelphia blacksmith. Its design was intended to allow quick cuts and forceful attacks capable of knocking down the opponent in combat.

In the famous painting Washington Crossing the Delaware, by the painter Emanuel Leutze, a refined weapon can be seen on the general's left side. However, it is known that that sword did not reach his hands until several years later. It is believed that during the momentous crossing of the Delaware River in 1776, the weapon Washington actually carried was the lion's head cutlass.

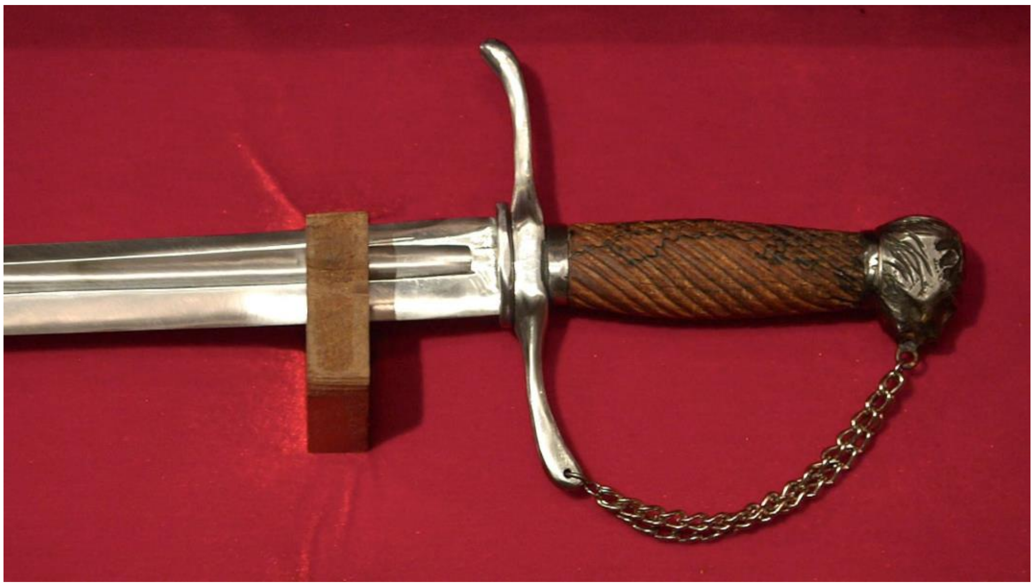


Some characteristics that stand out of this emblematic sword are the following:

• Curved, single-edged blade: Its length varies between 71 and 76 cm, which allowed a combination of speed and forcefulness in combat.

• Distinctive hawk: Features a rising rear hawk and a descending front hawk, designed to improve balance and maneuverability.

• Lion's head knob: This iconic detail not only provided a distinctive design, but also reinforced the handle, providing security in the grip.



While there are several depictions of Washington's weapons, the lion-headed cutlass is one of the most iconic due to its role in the early years of the war. The sword we have crafted attempted to meet most of the original features, ensuring that its design accurately reflects the style and functionality of the weapon used by the general at key moments of American independence.

This project not only pays homage to history, but also demonstrates the impact of manufacturing in creating pieces with both symbolic and functional value. Unlike the techniques used in the 18th century, we implemented more advanced manufacturing processes, incorporating new technologies that allowed us to optimize the precision of the design, improve the properties of the material and guarantee a high-quality finish. This represents the evolution of foundry and metallurgy, fusing historical knowledge with modern innovation.

Design process and material selection

After an exhaustive investigation, the sword was designed using SolidWorks software, considering the weight, length and width specifications required by the Project. Additionally, the desing was inspired by one of George Washington´s classic swords.

Once the desing was completed, the selection of manufacturing materials was carried out. Various factors were considered, one of the most important beging the density of the delected marerials, as in directly influenced the final weight of the sword. Another critical factor was the selection of tooling, ensuring that the integration of the sword mold would not negatively impact the production process of the company where the project was developed.

Regarding tooling selection, the alloy of the sword was carefully considered, ultimately choosing 1076 steel as the material of choice.

For the manufacturing of the handle, aluminum and bronce were selected, considering their densities to avoid adding excessive weight to the sword. These components were produced using CNC machine, with bronce serving an aesthetic purpose in the sword´s desing.

Following the selection of the Blade alloy tooling, the work and challenges continued with modifications to the mold´s gating system. The objetive was to chieve a laminar and continuous Flow throughout the mold, ensuring complete filling whille minimizing the formation of cracks and porosity in the both the company´s production parts and the sword.

The entire process was successfully designed and executed with the support of Caterpillar engineers, utilizing the SolidWorks and Magma software to perform simulations. These simulations were critical in the optimizing the gating system and indentifying potential issues that could arise during the production of the sword Blade.

Once the tooling selection was completed and an appropiate gating system simulation was conducted, the production of the tooling proceeded. This tooling would serve as the model of the sword mold and, in this case, function as a core within the final mold where the molten material would be poured, the model was manufatudes using CNC machinery in Wood, as it vas deemed the most viable option for its production.

The molding system used for the sword´s production was the cold box process, as it alings with the manufacturing process utilized by Caterpillar. The sword mols was produced with the assistance of the “palmer” machine, which involves mixing sand, resins, and catalyst. This mixture is pured in the model, and whit the help od and main force, the sand is evenly distribited throughout the model to create the final mold containing the cavity for the sword Blade.

During this stage of thge process, issues arose when applying crack-resistant coating to the molds, after application, the molds warped, preventing the proper closure of the Blade mold. An analysis of the problema conclueded that the deformation was caused by the drying process of the coating, which was correlated with the surface of the molds were left to dry and the mold thickness, since the mold was relatively thin, it absorbed the coating more significantly, leading to deformation, ultimately, the decisión was made to avoid applying the coating to the sword mold to prevent these issues.

Once the sword mols were completed, they were paced within the tooling for the production of the final mold, where the sword Blade would be cast. As previusly metioned, the sword mol functionel as a core within the final mold.

The final mold was produced using the same process as the Blade mold, eploying the cold box system. The mold was filled with sand pre-mixed with resins (part 1 and part 2) and catalyst. Simultaneously, during the sand pouring process, vibrations were induced to ensure all cavities of the model were completely filled with sand. One of the challenges at this stage preventing the movement od the sword mold during vibration induction.

Once the model was fully filled, two trained operatorsm familiar with the machinery, evenly distributed the remaining sand and leveled the Surface of the mold.

During the desmolding process, a rollover machine was used. This machine applies pressure to the mold, rotates it 180°, and induces vibrations to release the mold from the model, ensuring a firm mold while preventing issue.

Fortunately, throghout the molding and demolding process, no fractures ocurred in the mold, successfully avoiding a common issue.

In the first mold produced, a slight misalignment was detected at the metal entry point, allowing sand to enter the sword Blade mold, which could have led tos and inclusions, to resolve this issue, modeling clay was applied at the junction between the runner and the sword Blade mold. This solution was effective, as the subsequent two molds no longer exhibited the problem.

Once them molds were completed, they were coated with Paint, cured, air-blasted, and finally sealed to proceed to the pouring stage.

The alloy melting process was carried out un an electric furnance, where the chemical composition adjustments were also performed. The molds were poured at a temperatura range of 1580°-1600°C, after the solidification period, the molds were transferred to a cooling chamber to ensure controlled cooling of the cast components over a 20 hour period.

Following the cooling phasem the demolding of the parts was performed, followed by a superficial cleaning of the sword Blade.

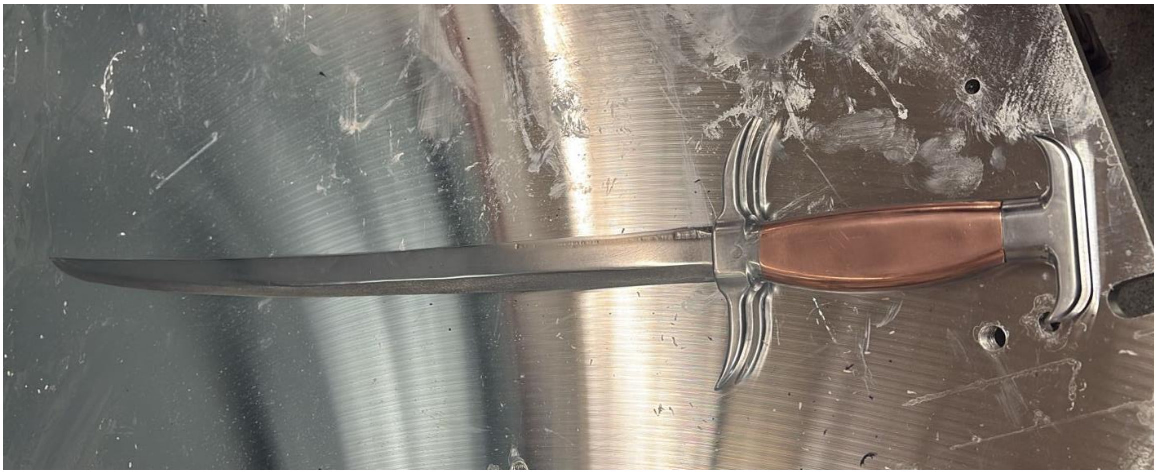
To enhance the mechanical properties of the piece and homogenize its microestrructure, a heat treatment process was selected, specifically normalization.

The choice of this treatment was bases on the blade´s dimensions and thickness, as a quenching prosed, a risk of fractures along the length of the sword, the normalization process was carried out in a continouns furnance at approximately 900°C, allowing the microestructure to become fully homogeneous (austenitic pase). After heating, the piece was left to air-cool completely at ambient temperatura, which during that day of the process range beween 23-25°C

As part of the Surface finishing process, the sword Blade was ground with the assistance of a trained engineer. Following machining, the Blade was sharpened using a grinding Stone, polished with a metal buffing compound, and then assembles with the aluminum and bronze handle.

Final result

The final product is a sword by George Washington, featuring a 1076 steel Blade, an aluminum hanlde, and bronce detailing. The sword has a final weight of 1.54 kg an a total lenght of: 96 cm



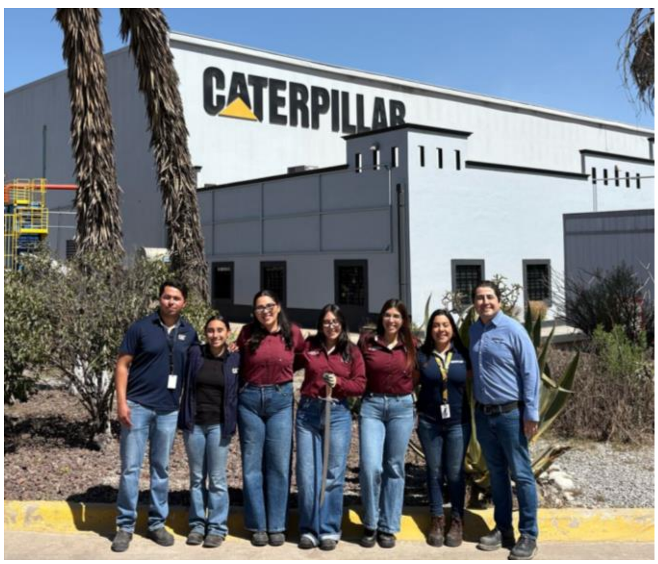
Conclusion

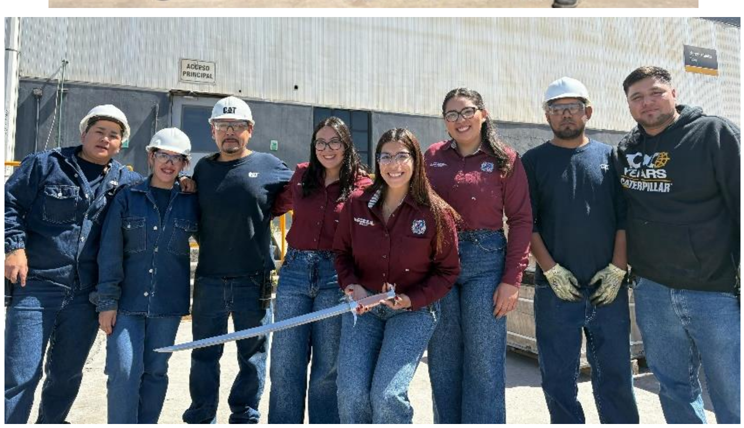
- Throughtout the entire process, we gained valuable experience as students, learning about the cold box molding process an the many challenges that can arise.
- A heat treatment was performed to enchance the sword´s final mechanical properties.
- Upon completing the finishing processes, a crack, porosities, ann microporosities were identified. An analysis was conducted, concluding that the crack might have resulted from the absence of the crack-resistant coating, which was omitted due to issues encontered during molding. Other potential causes include residual stresses within the microestructure or a machining defect.
- Regarding the porodities, one hypothesis suggests the may been caused by trapped gases during casting, as the sword mold was located in a section far from the vents.
- Throughout the Project, we were able to improve and develop skills in analysis, problem- solving, proactivity, and, most importantly teamwork.
- the final microestructure obtrained was pearlite, which is characterized by its toughness, lower internal microestructural distortion, improved mechanical strenght, and Good machinability.

Acknowledgments

We want to express our deepest gratitude to all the people who made this project possible with their support and guidance.

- To our industrial partner, Caterpillar, for providing us with their support and accompanying us in every stage of the molding and casting process, every piece of advice, no matter how small, was of great help to us. Without his guidance, this project would not have been a reality.
- To Dr. Almanza, for his constant support and for being a key mentor throughout this challenge.
- To our families, for being our greatest support, encouraging us to continue learning and always giving our best.
- And, of course, to each member of our team, for building a friendship based on effort and perseverance, for never giving up and for supporting each other every step of the way.





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