SFSA Cast in Steel 2025 – Horseman's Axe
Technical Report

Ecole nationale supérieure des Arts et Métiers – Forge and Fratern'ss

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Safe metal

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I. Executive Summary

The Steel Founders' Society of America created the Cast in Steel Competition to encourage students to learn about the manufacturing of steel products using casting processes while applying modern technologies and engineering methods. The competition provides engineering students with the opportunity to combine theoretical knowledge with practical manufacturing experience through the design and production of a functional steel object.

The team Forge and Fratern'ss, composed of five students from the Arts et Métiers Institute of Technology at the Cluny campus, designed and manufactured a cavalry axe inspired by European weapons from the late Middle Ages. During this historical period, axes used by mounted soldiers began to combine efficient combat geometry with decorative elements that reflected the artistic and cultural influences of the time.

The design developed for this project integrates historical inspiration with elements representing the traditions of the Cluny campus. The spike located at the top of the axe head was inspired by the architecture of the clock tower of the historic Abbey of Cluny. Additionally, the center of the axe head contains a hole forming the logo of the Arts et Métiers students' association. This feature was created directly during the casting process using a sand core.

The axe head was manufactured using a sand-casting process. This manufacturing technique was selected because it allows the production of complex geometries while remaining a traditional and widely used industrial process. Several castings were produced to ensure the quality of the final component and to allow the team to select the best specimen for finishing.

The material selected for the axe head was 35CrMo4 alloy steel, which offers high mechanical strength and excellent hardenability. After casting, a localized oil quench heat treatment was applied to the cutting edge of the blade in order to improve hardness and cutting performance while preserving sufficient toughness in the rest of the structure. Finally, a burnishing process (black oxide finish) was performed on the entire head to enhance corrosion resistance and provide an authentic historical aesthetic.

Non-destructive inspection was initially performed through visual inspection to detect possible surface defects. The final axe combines historical authenticity, modern engineering tools, and traditional casting technologies, demonstrating the educational value of integrating metallurgy, design, and manufacturing processes.

II. Introduction

The Cast in Steel Competition organized by the Steel Founders' Society of America aims to promote knowledge of steel casting technologies among engineering students. Through this competition, participants are encouraged to design and manufacture a steel object using casting processes while applying modern engineering tools and manufacturing techniques.

Casting is one of the most versatile manufacturing processes used in the metal industry. Unlike machining or forging, casting makes it possible to produce complex geometries directly from molten metal. This capability allows engineers to integrate functional details, decorative elements, and structural features within a single manufacturing step.

The objective of the project presented in this report was to design and manufacture a cavalry axe inspired by historical European weapons. The project combined historical research, mechanical design, metallurgy, and manufacturing processes. Particular attention was given to the integration of symbolic elements representing the traditions and heritage of the Cluny campus of the Arts et Métiers Institute of Technology.

III. Historical Background of the Cavalry Axe

Axes have been used as tools and weapons for thousands of years across many civilizations. During the late Middle Ages, cavalry axes were commonly used by mounted soldiers because they combined versatility, impact force, and relatively simple construction. These weapons were particularly effective against armored opponents and could deliver powerful blows capable of damaging armor or unseating riders.

European cavalry axes from this period often featured a cutting blade designed for slashing attacks combined with a spike that could be used to penetrate armor. Compared with earlier medieval axes, designs from the late Middle Ages began to include more decorative elements and more refined geometries. These decorative features often reflected the artistic influences and cultural identity of the region where the weapon was produced.

The axe designed by our team follows this historical inspiration while integrating modern design elements related to the Cluny campus of the Arts et Métiers Institute of Technology. The spike located at the top of the axe head was directly inspired by the architecture of the clock tower of the historic Abbey of Cluny. The architectural details of this tower, including its windows and roof structure, influenced the geometry of the spike integrated into the axe design.

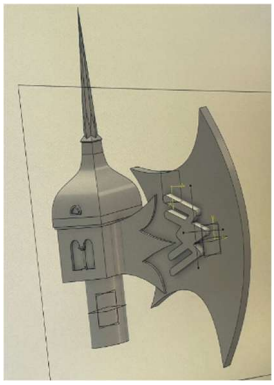
Another symbolic element of the design is the presence of a central hole representing the logo of the Arts et Métiers students. This feature connects the historical inspiration

of the weapon with the traditions and identity of the engineering school where the project was developed.

IV. Design Process

The design process began with a collaborative brainstorming phase during which the team explored several possible shapes and design concepts for the axe. During this stage, multiple sketches were produced by the team members in order to visualize different design possibilities and to discuss the aesthetic and functional aspects of the weapon.

Once the team reached an agreement on the overall concept, the design was transferred into a digital environment using the 3DEXPERIENCE CAD platform. This software allowed the team to create a detailed three-dimensional model of the axe and to refine the geometry with a high level of precision.



Each component of the axe was modeled separately before being assembled in the digital environment. The blade, the spike, the wooden handle, and the decorative brass components were all designed individually. This modular approach allowed the team to adjust the geometry of each element independently and to ensure that the final assembly was coherent both structurally and aesthetically.

Particular attention was given to the manufacturability of the design through casting. Draft angles, wall thicknesses, and mold removal constraints were considered during the CAD modeling process in order to ensure that the part could be successfully produced using sand casting.

V. Pattern Manufacturing and Mold Preparation

In order to manufacture the molds required for casting, the team produced patterns using additive manufacturing. The digital models created during the design phase were exported and used to produce physical patterns using 3D printing technologies available on the campus of the Arts et Métiers Institute of Technology.

These printed patterns were then used to create sand molds for the casting process. In addition to the external mold cavities, sand cores were produced to generate the internal cavity forming the logo located at the center of the axe head.

The preparation of the molds involved several manual steps typical of traditional sand-casting processes. The molding sand was first prepared and compacted around the patterns inside the mold boxes. Once the sand was properly compacted, the patterns were carefully removed to leave the mold cavity. The sand cores were then positioned within the mold in order to form the internal geometry required for the logo feature.

Due to the relatively large mass of the axe head, the feeding system was carefully designed to avoid shrinkage defects. The team decided to use three risers to ensure proper feeding of the metal during solidification.

VI. Casting Process

The axe heads were manufactured using a sand-casting process performed in the foundry facilities of the Arts et Métiers Institute of Technology. Sand casting was selected because it allows the production of complex geometries and remains one of the most widely used casting processes in the metal industry.

The steel used for the casting was heated to approximately 1630°C before pouring. Once the molten steel reached the appropriate temperature, it was poured into the prepared sand molds under the supervision of experienced instructors.

After pouring, the molds were left to cool and solidify. During this cooling phase, the team cleaned and organized the workspace before returning later to remove the castings from the molds. The removal of the casting from the sand mold, commonly referred to as shakeout, was followed by cleaning operations and the removal of excess material.

Approximately ten axe heads were produced during the casting campaign. Producing multiple castings allowed the team to compare the quality of the different parts and select the best specimen for final finishing.

VII. Metallurgical Considerations

The material selected for the axe head was 35CrMo4 alloy steel. This chromium-molybdenum alloy steel is commonly used for high-strength mechanical components because it combines good toughness with high strength and good hardenability.

These properties make 35CrMo4 particularly suitable for tools and impact-resistant components such as axes or hammers. The presence of chromium and molybdenum in the alloy improves the steel's hardenability and contributes to enhanced mechanical performance after heat treatment.

After casting and cleaning, a localized heat treatment was performed. The cutting edge was heated and subjected to an **oil quench**. This medium was selected to achieve the required hardness while minimizing internal stresses and the risk of cracking in the 35CrMo4 alloy. Following the heat treatment, a burnishing process was applied. This chemical surface treatment created a protective black oxide layer, significantly increasing the axe's resistance to atmospheric corrosion while reinforcing its historical appearance.

VIII. Value Added Through Casting

One of the major advantages of the casting process is the possibility of integrating complex geometries directly during manufacturing. The axe developed by the team includes several features that demonstrate the design freedom offered by casting technologies.

The central logo cavity was created using a sand core placed inside the mold during the casting process. This feature would have been difficult to produce using conventional machining methods. The spike of the axe also contains architectural details inspired by the tower of the Abbey of Cluny, including window openings and roof-like structures that reproduce the visual identity of the building.

The blade itself also presents an asymmetric geometry, which contributes to the historical aesthetic of the weapon while demonstrating the ability of casting to produce complex shapes without requiring extensive machining operations.

IX. Inspection and Non-Destructive Testing

Ensuring the structural integrity of the casting was an important part of the manufacturing process. After the castings were removed from the molds and cleaned, each piece was inspected visually to detect potential surface defects.

The visual inspection focused on identifying possible cracks, shrinkage cavities, or incomplete filling defects that could compromise the structural integrity of the axe head. By producing several castings, the team was able to compare the different parts and select the casting that presented the best overall quality.

Additional non-destructive testing methods may be performed in the future to further evaluate the integrity of the selected casting.

X. Assembly and Finishing

Once the final casting was selected, finishing operations were performed in order to prepare the axe for final assembly. These operations included grinding, deburring, and sharpening of the cutting edge. The steel head then underwent a burnishing treatment to achieve its final black finish before being fitted onto the ash wood handle.

The handle of the axe was manufactured using ash wood, a material traditionally used for tool handles due to its combination of strength, flexibility, and resistance to shock. Decorative brass components were also manufactured and placed near the guard area to enhance the visual appearance of the weapon.

The final assembly involved fitting the axe head onto the wooden handle and integrating the decorative elements in order to produce a functional and aesthetically coherent object.

XI. Final Specifications

The final dimensions and weight of the axe will be measured once the assembly and finishing operations are completed.

The axe head is manufactured from 35CrMo4 alloy steel, while the handle is made from ash wood. Decorative elements were produced using brass.

XII. Project Organization

The project was carried out by a team of five students from the Arts et Métiers Institute of Technology. Responsibilities were distributed among the team members according to their technical interests and skills.

Some students focused primarily on the digital design of the axe using CAD tools, while others worked on pattern manufacturing, mold preparation, or the fabrication of the wooden handle and brass components. Despite these individual responsibilities, most stages of the project were completed collaboratively.

The entire project lasted approximately six months, from the initial design phase to the casting and finishing of the final axe.

XIII. Conclusion

The project carried out by the Forge and Fratern'ss team demonstrates the integration of historical inspiration with modern engineering tools and traditional casting techniques.

Through the design and manufacture of a cavalry axe inspired by late medieval European weapons, the team explored the complete process of developing a cast steel product.

The use of sand casting allowed the integration of complex geometrical features and symbolic elements while maintaining a manufacturing approach consistent with traditional foundry practices. The selection of 35CrMo4 alloy steel and the application of localized heat treatment ensured that the mechanical properties of the axe head were suitable for its intended function.

Participation in the Cast in Steel Competition provided valuable practical experience in casting technologies, metallurgy, and collaborative engineering design. The project illustrates how traditional manufacturing methods such as casting remain essential in modern engineering education and industrial production.