CAST IN STEEL 2026

Horseman's axe

"Les Cavaliers de Bussy"

Thanks

We would like to express our sincere gratitude to all the organizations and teams that contributed to the completion of this project.

- **Ferry:** We extend our deepest thanks to Ferry for their overall supervision of the project, their technical expertise in steel and manufacturing processes, and their continuous support in project monitoring and communication.
- **FAD (Denain foundry and steelworks):** We are immensely grateful to the FAD for their invaluable technical guidance, particularly in material selection, metal charge preparation, and process control.
- **The Lycée (Armentières):** We also warmly thank the Lycée, including the foundry students, for their dedicated involvement in the practical execution of the project. Their hard work in molding, pouring operations, 3D printing, pattern making, and the final finishing of the axe was essential.

Finally, we thank all the teams within these entities for their availability, their willingness to share their expertise, and their commitment, which greatly contributed to the success of this project.

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Introduction

"Les Cavaliers de Bussy" team is honored to take part in the *Cast in Steel* competition, tasked with casting a robust and functional Horseman's Axe. This historical weapon must adhere to the competition's restrictions while meeting high standards of durability and effectiveness.

This final report establishes the overall framework of our action plan to produce the Axe. The goal is to produce an exceptional tool that meets the critical needs of horseman.

Reminder: the final axe must weigh less than 1.5kg and length less than 800mm.

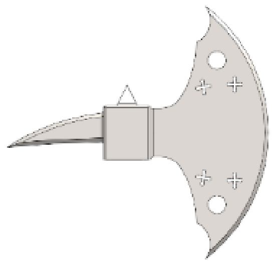
Presentation of the team

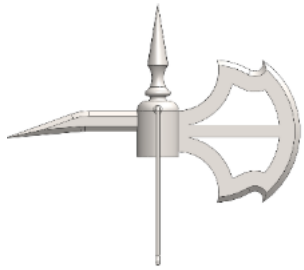
Team Overview This multidisciplinary team is composed of four ESFF students, combining their expertise in design, metallurgy, and project management for the Cast In Steel competition.

- **Tristan BRUNET (Ferry-Capitain) – *The Catalyst & Communicator*:** Initiated the project's momentum, actively participated in hands-on molding and casting, and managed the team's professional visibility on LinkedIn.
- **Thomas MOREAU (FAD) – *The 3D Designer*:** Transformed the initial concepts into manufacturable 3D models. He was heavily involved in production operations, from molding and casting to the intricate finishing of the axe blade.
- **Pierre PERSY (Ferry-Capitain) – *The Historical Researcher*:** Combined his passion for history with engineering by researching medieval weaponry and synthesizing the competition's technical guidelines. He also took an active role in molding, casting, and final polishing.
- **Angelo TRIVELLATO (Ferry-Capitain) – *The Team Leader*:** Leveraged his prior competition experience to oversee scheduling, deadlines, and alloy selection. Furthermore, he established a formal association to leave a lasting legacy for future student teams.

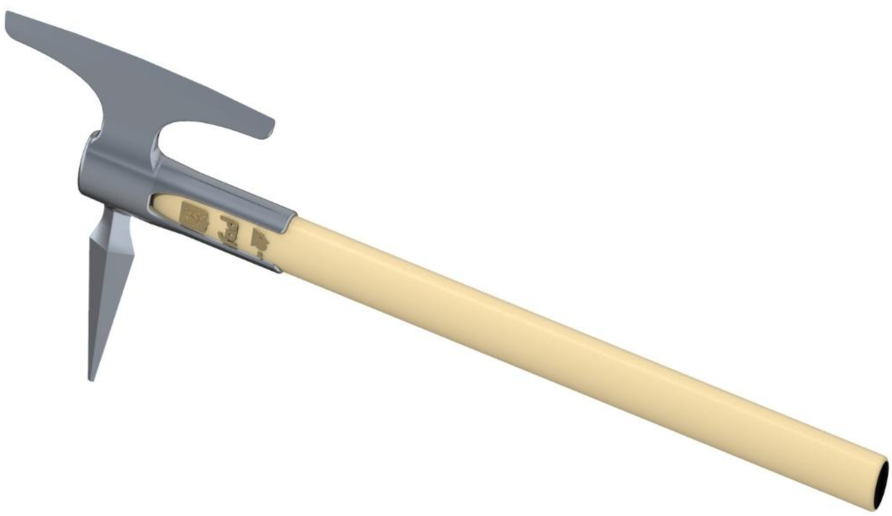
Conception of the axe

Early in the competition, we conducted a preliminary design phase that resulted in four potential axe-head geometries: round, oval, square, and "special."



We ultimately selected a square head design, perfectly tailored for mounted combat. This geometry balances a sharp cutting edge with a heavy, effective crushing power. Based on Cast In Steel guidelines, we removed the top spike from the design. This crucial choice eliminates a stress-concentration point and prevents structural failure. Removing the spike also allowed us to easily optimize the weapon's overall weight. Furthermore, it increased the surface area of both the primary blade and the rear poll. We incorporated reinforcing straps (languets) for a secure head-to-handle connection. For the blade itself, we opted for a solid, non-skeletonized profile. While slightly heavier, this maximizes the axe's mechanical robustness and integrity. The final design and its complete technical drawings are presented just below.



Definition of the alloy

55S7 steel is a silicon–manganese spring steel characterized by a high yield strength, good fatigue resistance, and excellent elastic deformation capability. It is commonly used in the manufacture of springs, torsion bars, suspension leaves, and other components subjected to significant dynamic loading.

The objective for our axe design is to withstand the highest possible impact loads without undergoing plastic deformation. It is considered that once plastic deformation initiates, the axe effectively begins to reach the end of its service life and will no longer remain operational for long. This is particularly critical in battlefield conditions, where pausing operations to perform heat treatment on equipment is not feasible. Therefore, the use of a high yield strength (HSS/HLE) steel was essential to meet our design requirements.

Furthermore, selecting a high yield strength steel highlights our technical capabilities and French expertise. This type of steel requires highly precise and rigorously controlled heat treatment processes. For the chemical composition, we targeted compliance with the DIN 17 222 standard for 55Si7 grade steel.

<table>
<tr><th>Chemical composition</th><th>C</th><th>Si</th><th>Mn</th><th>P</th><th>S</th><th>Cr</th><th>Mo</th><th>Ni</th></tr>
<tr><td>Max</td><td>0.52</td><td>1.60</td><td>0.60</td><td rowspan="2"><0.025</td><td rowspan="2"><0.025</td><td rowspan="2"><0.40</td><td rowspan="2"><0.10</td><td rowspan="2"><0.40</td></tr>
<tr><td>Min</td><td>0.60</td><td>2.00</td><td>0.90</td></tr>
</table>

We specifically chose an **interrupted oil quench (martempering)** strategy. This was a critical technical decision to minimize internal stresses and mitigate the risk of quenching cracks, which are common in high-carbon/silicon steels with complex geometries.

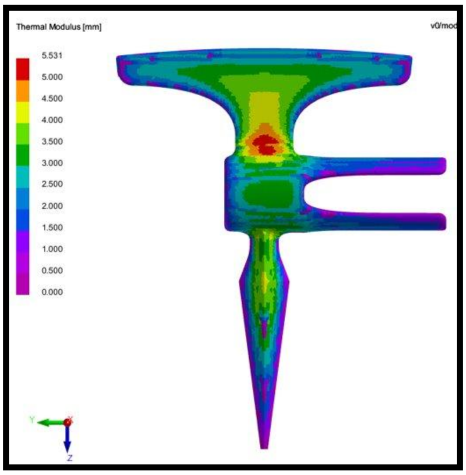
Heat Treatment Parameters:

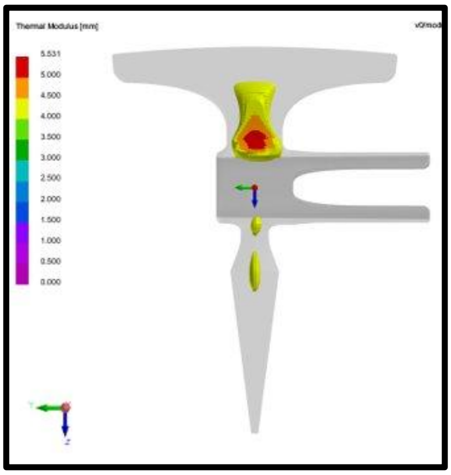
- **Normalizing:** 950°C (Soak time: 1h per 25mm + 1h).
- **Organic Oil Quenching:** 310°C (Soak time: 1h per 25mm + 1h). *We opted for oil quenching to reduce internal stresses and prevent thermal cracking.*
- **Tempering:** 600°C (Soak time: 1h per 25mm + 1h).
- **Target Hardness:** 250 HB.

Manufacturability and casting study

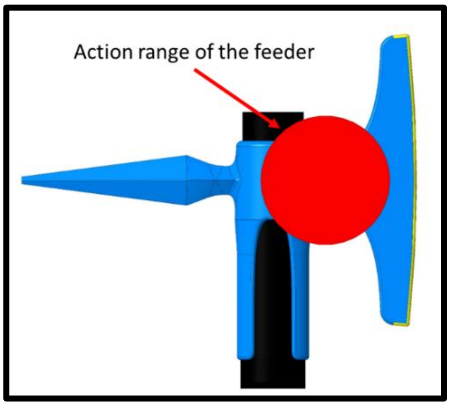
To ensure the structural integrity and internal soundness of the casting, we conducted a rigorous mold study centered on numerical simulation:

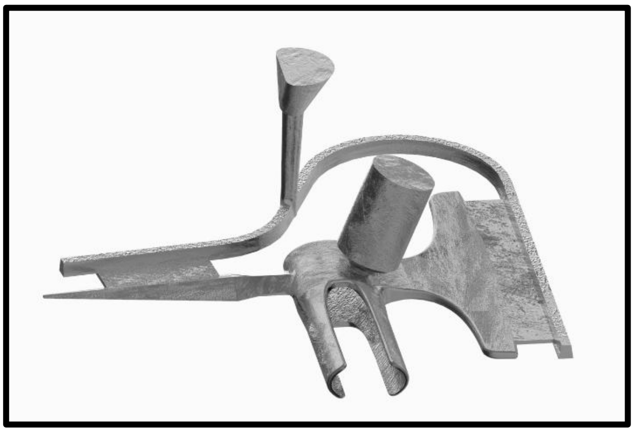
- Solidification Simulation: Using QuickCast software, we simulated the cooling process to pinpoint the "last-to-freeze" zones (hot spots). The analysis revealed potential thermal cut-offs near the handle and thinner sections of the blade. These isolated zones are critical, as they can prevent proper metal feeding and lead to shrinkage defects:





- Risering System Design: To counteract these risks and ensure a defect-free casting, we engineered a strategic risering (feeding) system. The sizing and placement of the risers were determined following the industry-standard guidelines and calculation methods established by the CTIF (the French Foundry Technical Center):

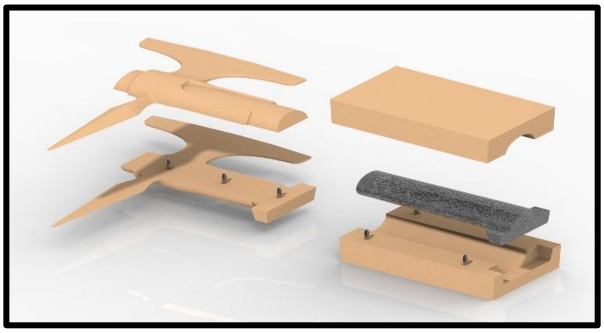




Patternmaking and tooling

We had the privilege of utilizing two different manufacturing methodologies for our tooling, bridging the gap between traditional techniques and new technologies.

Additive Manufacturing (3D Printing): The primary patterns and core boxes were produced using 3D printing at the FAD foundry. Utilizing 3D printing allowed us to achieve high geometric precision and rapid prototyping in the early stages of the project:



In addition to 3D printing, we employed a second manufacturing method: Strat conception using polystyrene, carried out at the Ferry-Capitain facilities. Utilizing these two distinct rapid prototyping techniques provided us with valuable insight into different tooling strategies:

Molding and production

The molding phase was a collaborative effort with the Foundry BTS students at Lycée Gustave Eiffel in Armentières, supported by Benoît SANTRAINE.

- The Mold: Produced using the traditional green sand process.
- The Cores: Manufactured using chemically bonded sand (self-hardening polyurethane system) to ensure high dimensional accuracy for the internal cavities.

After completing the molding of all our molds, we proceeded with pouring them using the alloy previously selected:

The shakeout (knockout) phase confirmed our success, revealing sound castings with good surface integrity:

Conclusion

Our axe is inspired by representations found in certain historical tapestries.

The idea of engraving the wood with blooming flowers symbolizes the arrival of spring, much like the coming of a long-awaited event after the months of autumn and winter. The arrival in the United States is thus envisioned as a rebirth, mirroring the renewal of spring. This approach also echoes the aesthetic of French formal gardens. The choice of ferrules stems from the toolmakers' desire to create durable and robust tools, capable of withstanding the test of time despite the fragility of the wood (particularly at the end of winter and the beginning of spring). They therefore ensure a longer lifespan for the axe. A long, slender point at its base, tapered along its entire length, is intended to be both piercing and elegant. It adds a touch of French refinement, in continuity with the engraved plant motifs that seem to flow into and out of the axe. The cold effect of the forging, combined with sharp and polished edges, creates a contrast between functional areas, precise and refined, and more raw sections, defined by their texture and shadow. The grip is enhanced with leather on the handle, symbolizing roots clinging to the rider. From afar, the axe evokes the softness of spring in bloom, up close, it reveals a formidable object, both piercing and razor-sharp.

Appendices

Gating system

Dimensionnement système de remplissage – Echelonnement 1 – 1,14 – 1,14

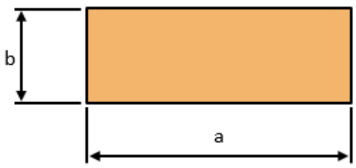
$$T_{l_{surchauffe\ de\ 150°C}} = 5\ s \Rightarrow T_r = 5\ s$$

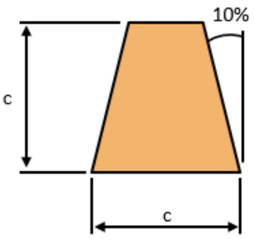
$$\boldsymbol{S_d} = \frac{V_{grappe}}{T_r \times \eta \times \sqrt{2 \times g \times H}} = \frac{310\,000 \times 1{,}1}{5 \times 0{,}55 \times \sqrt{2 \times 9810 \times 118{,}6}} \approx \mathbf{81,3\ mm^2}$$

$$\boldsymbol{a} = \sqrt{\frac{S_d}{2} \times 1{,}14 \times 4} = \sqrt{\frac{81{,}3}{2} \times 1{,}14 \times 4} \approx \mathbf{13,6\ mm}$$

$$\boldsymbol{b} = \sqrt{\frac{\frac{S}{2} \times 1{,}14}{4}} = \sqrt{\frac{\frac{81{,}3}{2} \times 1{,}14}{4}} \approx \mathbf{3,4\ mm}$$

$$\boldsymbol{c} = \sqrt{S \times 1{,}14 \times 0{,}9} = \sqrt{81{,}3 \times 1{,}14 \times 0{,}9} \approx \mathbf{9,1\ mm}$$





Gating system

Dimensionnement descente de coulée

$$\boldsymbol{d} = \sqrt{\frac{S \times 4}{\pi}} = \sqrt{\frac{81{,}3 \times 4}{\pi}} \approx \mathbf{10,2\ mm}$$

$$\boldsymbol{H_2} = H_i - c - d = 130 - 9{,}1 - 10{,}2 = \mathbf{110,7\ mm}$$

$$\boldsymbol{S_1} = S_d \times \sqrt{\frac{H_2}{H_1}} = 81{,}3 \times \sqrt{\frac{110{,}7}{40}} \approx \mathbf{135,2\ mm^2}$$

$$\boldsymbol{d_1} = \sqrt{\frac{S_1 \times 4}{\pi}} = \sqrt{\frac{135{,}2 \times 4}{\pi}} \approx \mathbf{13,1\ mm}$$