

SFSA Cast In Steel 2025 – Horseman’s Axe
Technical Report
University of Northern Iowa – Team Chop-Chop



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1. Introduction

The **Steel Founders' Society of America (SFSA)** has created this competition to encourage students to learn about making steel products using the casting process and applying the latest technology available. The Cast in Steel competition challenges engineering students to design, cast, heat treat, finish, and test a functional steel product while demonstrating metallurgical understanding, manufacturing competency, and quality control.

For the 2026 competition, the selected weapon is the Horseman's Axe. Our team's objective was to design and produce a historically accurate, fully functional Horseman's Axe using modern casting technology while meeting all competition specifications.

2. Historical Background and Authenticity

The Horseman's Axe emerged during the 15th century as mounted warfare evolved in response to widespread use of plate armor. Traditional swords became less effective against armored opponents, leading to the development of impact-focused weapons capable of delivering concentrated force and armor penetration.

Authentic horseman's axes typically feature:

- A compact axe blade designed for impact
- A rear spike or hook for piercing armor or unseating riders
- A reinforced eye section for handle durability
- A balanced head suited for mounted combat

Our design replicates these historical features. The blade geometry was modeled after documented 15th-century examples, incorporating a narrow cutting edge optimized for force concentration. The rear spike was designed to provide puncture capability consistent with period weapons. Proportions were carefully selected to maintain historical authenticity while complying with competition dimensional limits.

Although modern CAD and heat treatment methods were used, the geometry, mass distribution, and functional characteristics remain faithful to an authentic medieval horseman's axes.

3. Design Process

3.1 Concept Development

The design process began with historical research and dimensional analysis of surviving museum examples. Key performance requirements were established:

- Maximum length: 800 mm (31.5 in)
- Maximum weight: 1.5 kg (3.3 lb)
- Structural integrity under impact loading

- Proper balance for one-handed mounted use

3.2 CAD Modeling

The axe head was modeled using Autodesk Inventor. Multiple design iterations were created to refine:

- Blade curvature
- Spike geometry
- Eye geometry for handle fit
- Weight distribution

Figure 1: Design Iterations



A 3% shrinkage allowance for steel casting was incorporated into the design. A machining allowance was also added to allow post-cast finishing on the cutting edges.

3.3 Finite Element Analysis (FEA)

Finite Element Analysis was conducted to evaluate stress distribution during simulated impact loading. Areas of high stress concentration were identified and reinforced by increasing local thickness or adjusting geometry. Examples of these reinforced areas are around the shaft hole. This step ensured the final design would withstand impact forces without failure in the steel head.

3.4 Prototype Evaluation

3D-printed prototypes were used to assess ergonomics, proportions, and handle fit prior to final casting. These prototypes allowed rapid iteration before committing to steel casting (See figure 1).

4. Metallurgical Decisions

Material selection was critical to achieving the proper balance between hardness and toughness.

The candidate alloys evaluated were:

- 5160 spring steel
- 8630 medium carbon, low alloy steel
- 4140 chromoly steel

After evaluation, **8630** steel was selected due to:

- Excellent impact resistance
- High toughness after tempering
- Proven performance in impact tools

The metallurgical goal was to achieve:

- A hardened cutting edge for edge retention
- A tough, ductile core to prevent brittle fracture
- Resistance to chipping during impact

Heat treatment considerations consisted of:

1. Normalization at 1650°F to refine grain structure and relieve casting stresses
2. Oil quenching to achieve martensitic transformation
3. Tempering to reduce brittleness while maintaining hardness

Hardness testing confirmed the normalization heat treatment achieved the desired mechanical properties as other forms of treatment would make the edge too hard, increasing the chance of cracking and/or chipping.

4.1 Metallurgical Decisions

Material selection was critical to achieving the proper balance between hardness, toughness, and castability.

After evaluation of several candidate alloys, **AISI 8630 steel** was selected for the final axe head.

Why 8630 Steel?

8630 is a nickel-chromium-molybdenum alloy steel known for:

- Good hardenability
- High toughness
- Excellent impact resistance
- Good strength after normalizing heat treatment
- Improved ductility compared to higher carbon steels

Unlike high-carbon steels such as 1055 or 5160, 8630 contains alloying elements that enhance toughness and hardenability while maintaining good machinability and castability. The presence of:

- **Nickel** improves toughness and impact strength

- **Chromium** increases hardenability and wear resistance
- **Molybdenum** improves strength and reduces brittleness

These alloying additions make 8630 well-suited for dynamic loading applications such as impact tools.

4.2 Metallurgical Objectives

The metallurgical goals for the axe head were:

- Adequate surface hardness for edge retention
- High core toughness to resist fracture
- Resistance to crack propagation under repeated impact

4.3 Heat Treatment Process

The axe head underwent a **normalization** treatment to refine grain structure and relieve residual casting stresses.

This heat treatment produced a balanced microstructure capable of sustaining repeated impact loads without catastrophic failure.

Figure 2: Heat Treatment



5. Casting Process and Technology

5.1 Casting Process Selection

Resin bonded sand casting was selected over investment casting due to:

- Lower cost

- Faster turnaround
- Adequate surface finish for post-machining

While investment casting provides superior surface finish, sand casting allowed flexibility for iterative development and defect mitigation.

5.2 Casting Steps

1. Pattern preparation from finalized CAD model
2. Mold preparation using bonded sand
3. Gating and riser system design for proper metal flow and shrinkage compensation
4. Melting of 8630 steel
5. Controlled pouring into prepared molds
6. Cooling and solidification
7. Shakeout and removal of risers and gates

Figure 3: Gating Simulation

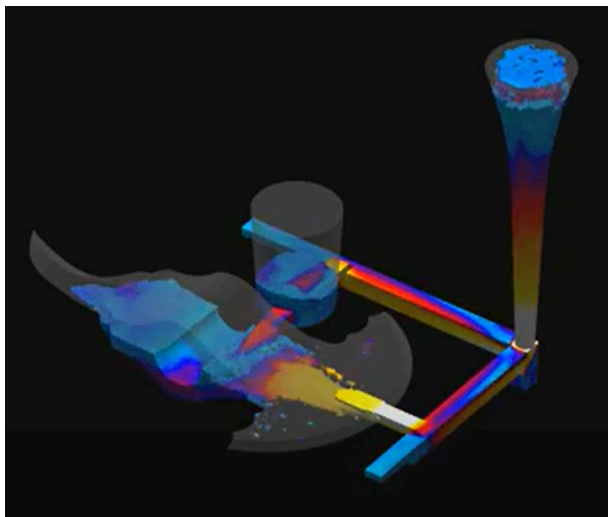


Figure 4: Pattern Creation



Figure 5: Pouring Steel



6. Use of Casting Technology to Add Value

Modern casting technology added value in several ways:

- CAD models were adjusted to ensure proper shrinkage allowances.
- Simulation-informed geometry reduced stress concentrations.
- Controlled gating and riser design improved metal flow.
- Multiple castings enabled quality selection and defect reduction.
- Heat treatment was performed using controlled furnaces rather than historical open methods.

These technologies improved dimensional accuracy, structural reliability, and repeatability while maintaining historical geometry.

7. Non-Destructive Testing (NDT) and Inspection

To ensure structural integrity, the axe underwent multiple inspection methods prior to submission.

7.1 Visual Inspection

Immediately after the shakeout, the casting was inspected for:

- Surface cracks
- Misruns
- Incomplete fill
- Warping

7.2 Surface Cleaning and Secondary Inspection

After grinding, bead blasting, and removing the gates and risers, additional inspection was performed to detect:

- Surface porosity
- Microcracks
- Inclusion defects

7.3 Hardness Testing

Rockwell hardness testing was conducted after heat treatment to verify mechanical property targets. Near the edge of the axe head was tested and a 27 HRC was reported.

These inspection and NDT steps ensured the integrity, safety, and functionality of the final product without complex equipment we did not have resource to.

8. Finishing and Assembly

After heat treatment, the axe head underwent:

- Grinding to final blade thickness
- Tumble polishing to reduce friction and improve surface finish
- Final sharpening

The handle, CNC turned from hickory, was fitted to the axe head. Proper fitment ensured safe and stable use under impact loading. The inverse taper allows the head to not slide off the top when swinging the axe.

9. Final Results and Contest Compliance

The completed Horseman's Axe meets all competition requirements.

Figure 3: Finished Horseman's Axe



Final Specifications:

- **Total Length:** 685 mm (27 in) (Well under the limit)
- **Total Weight:** 1.36 kg (3.0 lb) (Under the limit)
- **Head Material:** AISI 8630 steel
- **Handle Material:** Hickory hardwood and Deer leather

Mechanical Performance:

- Normalizing heat-treated for optimized hardness and toughness, while relieving internal stresses.
- Passed hardness verification testing, 27 HRC. Not very high in hardness, but this results in greater toughness. This allows it to withstand impact without cracking, while still being hard enough to maintain an edge.
- No cracking was observed after impact evaluation, and no cracking formed after heat treatment

The final product satisfies dimensional, weight, and functional requirements established by the competition.

10. Conclusion

This project successfully fulfilled the purpose of the SFSA Cast in Steel 2026 competition by applying modern casting technology, metallurgical principles, and engineering analysis to produce a functional steel product.

Our Horseman's Axe is historically authentic in geometry and purpose while benefiting from modern CAD design, simulation, controlled heat treatment, and NDT inspection methods. The final product meets all competition requirements and demonstrates the team's ability to integrate design, metallurgy, casting, testing, and quality control into a complete engineering solution.