SFSA Cast In Steel 2025 – George Washington's Sword

Technical Report

Tennessee Technological University – Foundry Fathers

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1.0 Introduction

Steel casting is a powerful blend of science, craftsmanship, and teamwork, requiring precision, collaboration, and dedication. The Steel Founders' Society of America (SFSA) created the Cast In Steel competition to encourage students to learn about making steel products, utilizing the latest technology available in the metal casting process. By participating, teams gain hands-on experience in metallurgy, design, and manufacturing while working together to overcome engineering challenges. This competition is more than just an opportunity to showcase technical skills; it is a chance to build lasting connections, develop problem-solving abilities, and demonstrate the resilience and innovation that defines great foundry work.

Our team, “The Foundry Fathers”, is inspired by the ingenuity and determination of America's earliest metalworkers whose craftsmanship helped shape a new nation. Just as they forged the tools of industry and revolution, we are forging an artifact that reflects both historical tradition and modern advancements in steel casting. Through collaboration, perseverance, and a commitment to excellence, we conquer the challenges of this competition with the same pioneering spirit that built America's industrial foundation. The Foundry Fathers aim to honor Washington's legacy by showcasing the art of metal casting to demonstrate that long-established manufacturing methods are still crucial for modern production today.

Beyond the technical aspects, this competition embodies the values of hard work, unity, and national pride. Steel casting has long been a cornerstone of American manufacturing, and through this experience, we are able to carry on that legacy. The

Foundry Fathers are honored to participate in an event that not only advances our skills but also strengthens the appreciation for the role of metal casting in shaping our world. With each molten pour, team members continue to celebrate the perseverance of those who came before us and the bright future each student is helping to create through teamwork and a shared passion for the craft.

2.0 History of Our Sword

2.1 Washington's Leadership and Need for a Great Sword

Twelve score and nine years ago, the great General George Washington crossed the icy Delaware River on a cold Christmas night to take the British army by surprise. Washington was a bold leader who thought outside the box when developing strategies in war and in politics as well. This great man led the Continental Army to a victory that no one thought to be possible. However, every great military leader needs an equally great sword to aid him in battle and to inspire courage in his men.

2.2 Origins of the Bailey Silver & Ivory Hilted Cuttoe

The Bailey Silver & Ivory Hilted Cuttoe sword is an artifact of historical significance, recognized for its association with George Washington. The sword was crafted by John Bailey, a highly skilled English-born cutler and swordsmith who immigrated to New York, USA in the mid-18th century. Bailey was renowned for his fine craftsmanship in edged weapons, blending European sword-making traditions with American materials and stylistic preferences. A light and elegant short sword, the cuttoe, was a favored weapon among military officers and gentlemen of the period.

2.3 Materials and Craftsmanship

The Bailey Silver & Ivory Hilted Cuttoe features a hilt constructed of silver and ivory, materials indicative of the high status of its owner. In the 18th century, swordsmiths commonly used high-carbon steels for functional blades. At this time steelmaking was a very different process than what we see today. To make high-carbon steel, the steelmaker would take wrought iron bars and layer them with charcoal to increase the carbon content of the steel. As a result of this process, it is hard to estimate what steel type would be most accurate for this period. Based on the concentration of manganese, that would most likely be present in the iron ore at the time, and the amount of carbon that would have been used, 1060 steel should serve as the best modern rendition of the steel used to make Washington's other swords. This sword is created with 1060 steel combined with 1566 steel, to enhance the hardness and durability of the blade.

The 1060 steel used is made up of 0.60 % Carbon, 0.80% Manganese, 0.40% Silicon and 0.25% copper. The alloy is composed of roughly 20% 1566 steel and 80% 1060 steel. This ratio of alloy offers good edge retention and resilience, making it a strong choice for the ivory cuttoe. Although Washington's original blade would have, most likely, been forged from wrought iron or early steel alloys with variable carbon content, this steel alloy closely replicates the characteristics of the materials the ivory cuttoe would have been made of in modern times.

The overall design reflects both functional military use and decorative prestige. By using our custom steel alloy in this project, our team can ensure historical accuracy and have a precise idea of what properties this blade will have to assist in the heat treatment and post-process stage.

2.4 George Washington's Use of the Sword

George Washington, then serving as the Commander-in-Chief of the Continental Army, carried the Bailey Silver & Ivory Hilted Cuttoe as part of his dress uniform. Unlike heavier combat swords, the cuttoe served as a symbol of leadership and authority, rather than a primary battlefield weapon. Washington was known for his meticulous attention to appearance and decorum, and this sword complemented his uniform during key moments of the Revolutionary War. The sword was notably worn by Washington in various formal military settings, including inspections, ceremonies, and council meetings with officers. Its presence in portraits and written records underscores its significance as a personal item of Washington's military attire.

2.5 Preservation and Historical Legacy

The Bailey Silver & Ivory Hilted Cuttoe has been carefully preserved as a historical artifact and is currently housed at the Smithsonian Institution. As a relic of Washington's leadership and the American Revolution, it continues to be a focus of study for historians and collectors. The craftsmanship of John Bailey remains exemplary of 18th-century American sword-making, and this particular piece serves as a testament to the refinement and status of Washington as a military leader.

2.6 Our Design Approach and Creative Vision

When designing the cuttoe replica and deciding on the metallurgical profile for the sword, the goal was to closely adhere to the respected metals and materials that John Bailey would have used to produce his sword. The detailed decisions made by our team will be discussed in their respective sections. Overall, the final product both pays homage to the greatness of Bailey's design while also taking creative liberties to express the heart of our team and respective school spirit.

3.0 Metallurgical Considerations

Metallurgical considerations are critical to ensuring the strength, durability, and historical accuracy of the replica of George Washington's Bailey Silver & Ivory Hilted Cuttoe. Since 1060 steel makes up the majority of the alloy, let's focus on its metallurgical properties. However, it's important to note the vast improvement the 1566 steel adds to the blade. The choice of 1060 steel for the blade provides an ideal balance of hardness and toughness. 1060 steel allows for proper heat treatment to enhance edge retention and flexibility. The addition of 1566 steel gives the sword better wear resistance due to its chromium content. Understanding factors such as cooling rates, grain structure, and alloy composition is essential in achieving the desired mechanical properties and historical authenticity. By applying both traditional and modern metallurgical principles, as well as using a mixture of 1060 and 1566 steel, the process ensures the final sword is both a faithful recreation and a well-engineered piece of craftsmanship.

3.1 Strength

1060 steel is considered high-carbon, with approximately 0.60% carbon content, giving it an excellent balance of hardness, strength, and toughness. This composition makes it ideal for sword blades, as it allows for proper heat treatment, enhancing both edge retention and durability while maintaining enough flexibility to resist breaking under impact.

The relatively high carbon content in 1060 steel allows it to be hardened through heat treatment, enabling the blade to hold a sharp edge over time. A well-treated 1060 steel blade will resist dulling, making it capable of maintaining its cutting ability with minimal maintenance. This is particularly important for a sword like the cuttoe, which, while often seen as a dress or ceremonial piece, was still expected to function as a sidearm in combat. The ability to take and hold a fine edge ensures that the blade would have been both practical and formidable if needed in battle.

While some steels can become too brittle when hardened, 1060 steel provides an excellent balance between hardness and toughness. This means the blade can absorb shock and resist chipping or breaking under stress, making it ideal for a sword that may experience impact during use. Unlike softer low-carbon steels that might bend easily or high-carbon steels that risk shattering, 1060 steel allows for controlled hardness, meaning it retains durability while still having a degree of flexibility. This is particularly important for a cast blade. Cast blades are more prone to internal stresses that need to be managed through proper post-casting heat treatment.

While 1060 steel is strong, it is still malleable enough to be worked through blacksmithing and polishing after casting. Once the blade is cast, it will need to undergo grinding, shaping, and heat treatment to refine its final form. The steel's composition allows for controlled heating and quenching, giving the team the ability to achieve the desired hardness while preventing warping or cracking. Additionally, 1060 steel polishes well, allowing for a smooth, refined finish that enhances both the aesthetic appeal and functional integrity of the blade. The ability to shape and fine-tune the steel after casting is crucial for achieving a historically accurate and high-quality replica.

3.2 Ductility

Ductility refers to a metal's ability to undergo plastic deformation—bending or stretching—without breaking. In cuttoe sword making, ductility is a critical factor because it affects how the blade responds to stress, impacts, and post-processing techniques like forging, grinding, and heat treatment.

A sword that is too hard and lacks ductility may become brittle, making it prone to cracking or breaking under impact. When properly heat-treated, 1060 steel maintains a balance between hardness for edge retention and ductility to absorb shock, preventing catastrophic failure.

While a cuttoe is a shorter sword and not designed for heavy impact like a longsword, it still benefits from controlled flexibility. If struck against a hard surface or subjected to stress, a ductile blade can bend slightly and return to shape rather than snapping. This ensures durability in both practical use and long-term preservation.

Since this sword blade is being cast, ductility is especially important because the casting process introduces internal stresses and potential microscopic defects. A material with sufficient ductility can tolerate small imperfections better than one that is too rigid. Additionally, post-casting processes like grinding, polishing, and heat treating require the metal to be workable without cracking.

The tempering process plays a crucial role in optimizing the ductility of 1060 steel. If the steel is quenched too aggressively, it can become excessively hard and brittle. Tempering after quenching reduces this brittleness by slightly softening the steel, restoring some ductility while maintaining enough hardness for a sharp edge. Proper heat treatment ensures the blade has enough give to prevent breakage but remains strong enough for cutting and durability.

3.3 Hardness

Hardness is a material's resistance to indentation, wear, and scratching. In the context of sword making, hardness is an important factor because it directly impacts a blade's ability to retain its edge and resist wear over time. For swords, achieving the right level of hardness is crucial for ensuring the blade can maintain its sharpness during use while being resistant to damage from both cutting and environmental factors.

A hard blade will hold a sharper edge for a longer period, making it ideal for slicing or cutting tasks. The 1060 steel used for the blade of this replica sword is hard enough to provide excellent edge retention, which is especially important for a weapon that was intended to have both functional and ceremonial uses. Hardness ensures that the blade doesn't dull quickly and maintains its cutting ability with minimal sharpening.

Hardness contributes to a blade’s ability to resist wear and tear over time. For a sword like the cuttoe, which would have been exposed to constant handling and potential use in combat or ceremonial displays, hardness helps prevent the blade from developing nicks, scratches, or worn edges. A harder steel will withstand these stresses better than a softer material, maintaining its integrity for much longer.

While hardness is important, it must be balanced with toughness. Toughness is the ability of the material to absorb energy and deform without breaking. In sword making, if the blade is too hard without sufficient toughness, it could become brittle and prone to cracking or breaking under impact. This is why 1060 steel is chosen—it provides the optimal balance between hardness (for edge retention) and toughness (for shock absorption and resilience). Proper heat treatment during forging allows the steel to achieve the right hardness without sacrificing durability.

4.0 Design Process

4.1 Brainstorming Phase

The project began with an extensive study of historical references to ensure accuracy in both form and function. Our team examined historical paintings and existing replicas to gather insights into the blade’s profile, hilt design, and material composition. The primary focus was on balancing aesthetic authenticity with manufacturability. The team sketched multiple design variations, evaluating different hilt geometries and blade tapers to determine the most suitable configuration. Material selection was another key consideration, as the sword needed to be both historically accurate and suitable for casting. After several discussions and evaluations, a final design concept was selected, ensuring that the sword would be practical for our casting and finishing processes.

4.2 SolidWorks Design Phase

With the conceptual design established, the next step was translating it into a 3D model using SolidWorks. The blade was modeled with careful attention to its curvature, tapering, and overall proportions (Figure 1 & 2). Our team made the blade wider from spine to edge and the tip thicker to allow for more material to work with during post-processing. The hilt was designed to incorporate aspects of school spirit and historical elements seen in the original sword while maintaining structural integrity (Figure 3 & 4). After the blade was designed, the gating system was shaped to supply the blade with an even distribution of metal through the casting process. The runner bar runs along the spine of the blade with six ingates that supply an even spread of steel along the sword. Additionally, finite element analysis (FEA) was performed to evaluate stress distribution, particularly at the tang-hilt junction, where structural weaknesses could arise. After multiple iterations and adjustments based on feedback, the final SolidWorks model was approved for production.

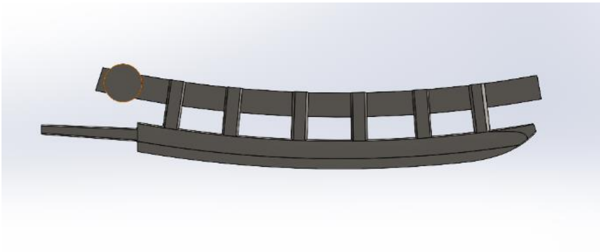
Figure 1: Blade Top View

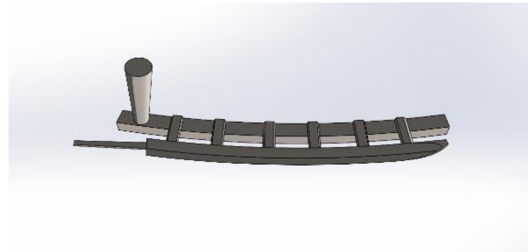
Figure 2: Blade Isometric View

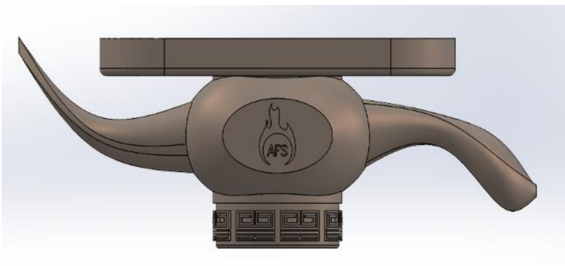
Figure 3: Guard Rear View

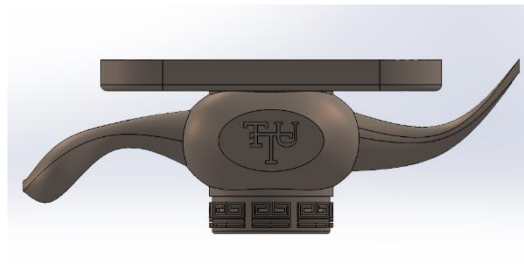
Figure 4: Guard Front View

5.0 Casting Process Selection

5.1 Blade Casting Process

The green sand-casting method was selected for the blade due to its availability, familiarity, and cost-effectiveness. On Tennessee Tech’s campus, sand casting is a well-established process, allowing us to utilize existing equipment and faculty expertise. Our team has prior experience working with green sand; therefore, we efficiently create molds with confidence, reducing the likelihood of errors that may arise from using unfamiliar methods. Additionally, green sand casting is a widely used industrial process, making it a practical choice for learning real-world manufacturing techniques.

Another key factor in the decision was the repeatability and affordability of green sand casting compared to other methods, such as investment casting. Green sand molds can be easily prepared and reused, which enables our team to refine the casting process through multiple iterations, if needed. This flexibility is critical for achieving a high-quality final product while staying within the constraints of the competition timeline. In contrast, investment casting requires more complex mold-making steps, increasing both the time and cost of production. By choosing green sand, the process remains efficient and economical while maintaining high casting quality.

Green sand also provides excellent heat resistance, making it well-suited for handling molten steel. The no-bake sand casting process, while also viable, was not chosen due to the complexity of operating the required machinery. No-bake systems require additional setup and specialized equipment, which can introduce challenges and delays in a competition setting. Green sand, on the other hand, offers a straightforward molding process with reliable thermal stability, ensuring that our molds remain intact under high temperatures. These advantages make green sand casting the optimal choice for our project, balancing accessibility, reliability, and cost-effectiveness.

5.2 Hand Guard Casting Process

The hand guard for the sword was lost PLA investment cast in bronze to achieve the highest possible quality and detail. Investment casting, also known as lost wax casting, allows for the creation of highly intricate and precise components by using a wax model that is coated in a ceramic shell before being melted away and replaced with molten metal. Bronze was chosen for the hand guard due to its historical accuracy, strength, and corrosion resistance, ensuring both durability and an authentic appearance.

Compared to sand casting, investment casting produces a smoother surface finish and finer detail, which was essential for replicating the elegance of the original Bailey Silver & Ivory Hilted Cuttoe. By using this method, we were able to achieve sharp definition in the guard's decorative elements, minimizing the need for extensive post-casting machining and polishing. This technique ensured that our final product met both structural and aesthetic standards while maintaining a strong connection to traditional craftsmanship.

6.0 Manufacturing Process

6.1 Flask and Match plate Fabrication

Once the design was finalized, a match plate and flask system were created to facilitate the green sand-casting process. The flask was custom made for the project because our team did not have access to a flask long enough to cast the blade (Figure 6). The match plate was also fully designed in house (Figure 5). In the process, the blade and runner bar were split into four pieces respectively and 3-D printed each piece. Those pieces were tacked to a wooded board taking consideration to align each piece with careful precision. The alignment and fit of these components were carefully verified to prevent mold shifting during the casting process.

Figure 5: Matchplate Construction


Figure 6: Flask Construction

6.2 Green Sand-Casting Process

Due to many factors, including our team's ambitions of completing the first ever steel casting made in the Tennessee Tech University foundry, the sand-casting process was chosen because each team member has experience with this method and felt it would be highly effective for this project. The casting process began with the preparation of the green sand mold. The match plate was placed in the drag, and molding sand was tightly packed around it to capture the details of the sword's design. The cope was then positioned, and gating channels were added to facilitate controlled metal flow. Once the mold was complete, molten steel was poured into the cavity, filling the shape of the sword. During the pour, it was realized the ammount of aluminum used to deoxiidize the molten steel was roughly half of what it needed to be, this would later become a major concern in the post processining phase. After allowing sufficient time for cooling, the mold was broken open to reveal the rough casting. Initial inspection showed some minor shrinkage and surface roughness, which were later addressed during the post-processing stage.


Figure 7: Blade Casting


Figure 8: Guard Casting

7.0 Post-Processing

7.1 Final Finishing and Assembly

After casting, our team partnered with the Appalachian Craft Center, which collaborates with Tennessee Tech, to refine, repair, and temper the blade. We began the shaping process using a bandsaw, carefully removing excess material and cutting a section from the spine to form the secondary edge on the back of the tip. During this stage, we discovered air pockets within the blade, a common issue in cast steel components. Due to the severity of the air pockets in the blade we decided not to attempt any further heat treatment. Upon closer inspection, we determined that the best course of action was to repair a significant crack in the blade before proceeding with further finishing.

With the major structural concerns addressed, we returned to the shop in Lewis, where we dedicated nearly five hours using an angle grinder to shape the blade further. This involved refining the profile, smoothing rough edges, and gradually filing a sharp edge along the length of the blade. As this process continued, the severity of the cavitation within the blade became more and more apparent. A large cavity forced our fabricator to remove almost two inches of the blade tip and resharpen the point by hand. Once the rough shaping was complete, we transitioned to the belt sander to refine the edge and achieve a cleaner finish. At this stage, we also ground down the tang to ensure a proper fit for the hand guard, making final adjustments for assembly.

The final step in post-processing was selecting and custom-shaping the wood for the handle. We carefully chose a material that would complement the historical aesthetic of the original design while providing a comfortable grip. The handle was then shaped and fitted onto the tang, ensuring a secure connection between the blade, hand guard, and grip. Through extensive shaping, grinding, and finishing, we transformed the raw casting into a functional and historically inspired sword, ready for presentation in the Cast in Steel competition.


Figure 9: Blade Refinement


Figure 10: Polished Guard

7.2 Final Analysis

The requirements for the competition were met by the final product. The cuttoe sword weighs in at 2.55 pounds, with an overall length of 29 inches. This achievement demonstrates the successful integration of both design and material selection, ensuring the sword's performance aligns with the desired specifications and functionality.

8.0 Inspection and Testing

To ensure the quality and performance of the sword for this casting competition, a spectrometer test was going to be conducted on the final alloy composition. This test would have allowed us to verify that the chemical composition of the steel met the desired specifications, ensuring the proper balance of carbon, manganese, and other elements critical for strength and durability. By confirming the alloy’s composition, the team could confidently assess whether the material selection and melting process was successful in producing a high-quality steel casting. Unfortunately, due to a previous accident with the spectrometer, it was unfunctional at our team's time of need.

In addition to chemical testing, our team performed a hardness test to evaluate the material’s mechanical performance. This test provided a quantitative measure of the steel’s resistance to deformation, which is crucial for ensuring that the sword maintains its structural integrity under stress. Hardness testing also helped to determine the effectiveness of the heat treatment process, including quenching and tempering, by confirming that the steel achieved the desired balance between hardness and toughness. These inspection and testing procedures were essential for validating the quality of the casting and ensuring that the final product met both competition requirements and the team’s performance expectations.

9.0 Future Revision

As this was the first time that steel had been cast in the Tennessee Tech Foundry, our team encountered several challenges that provided valuable learning experiences for future improvements. One major revision our team would make is adding more vents along the blade to allow trapped gases to escape during the casting process, reducing the likelihood of defects such as porosity or incomplete fills. Proper venting would enhance the overall quality and surface finish of the sword, ensuring a more precise final product. Another revision to our process would be to make sure our equipment is running properly before needing to use it. This would have saved us a good amount of heartache as we carried out this project. Additionally, better time management would greatly improve our efficiency and reduce rushed decision-making. Since casting steel requires careful planning, from mold preparation to heat treatment, allocating sufficient time for each step would help our team refine the process and achieve more consistent results. With these revisions, along with the experience gained from the first steel casting, our team would be better prepared to produce a higher-quality sword in future competitions.

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