Viking Axe Technical Paper

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Abstract

An important tool of all people during the Viking age, the axe, was used by the superstitious Norse on their quest to Valhalla. The University of Northern Iowa strived to recreate a decorative viking battle axe for the Steel Founders Society, with a high chromium medium carbon steel alloy, poured at Viking Pump Alloy Foundry, located in Cedar Falls, IA. These prestigious decorations were implemented to showcase knowledge of runes and their symbols, as well as precise design work. The design was rigged and simulated using a process simulation software numerous times to eliminate defects. The final castings verified the simulation results, with no observed defects. A handle sculpted from ash wood was used to house the blade.

Introduction

The Vikings, also known as the Germanic Norse, were a group of seafaring raiders who explored and traded around the world for prestige and power. They were constantly traveling to conquer and expand to attempt to gain more prestige and power, in the form of: land, precious stones, and money. The Vikings were an incredibly superstitious people that believed in the Pagan Norse Mythology as they fought to expand. One aspect of this mythology is the equivalent of christian heaven, Valhalla. Valhalla is where the Viking god, Odin, lets the worthy reside after death if they have met their demise in battle. To gain entrance to Valhalla, instead of the

underworld, Hel, was the ultimate honor. Many Viking warriors lived their lives striving to be able to live forever in Valhalla.[1]

Where the sword was considered a weapon of prestige for the wealthy and social elite, the axe was the weapon of the common man. At this time, Axes were forged from iron, as steel had not been invented until a much later date. These Viking axes were typically used as tools on top of being weapons, and tended to be plain due to their utilitarian use. The wealthy did sometimes incorporate copper, silver, or gold decorations onto the blade. During this time, axes were formed in many different shapes and sizes, from the farm axe to the ones designated for battle. When masterfully created, the battle axe is balanced well, and the curved edge concentrates the blow's force into a small section of the edge, so the axe can power its way through helmets or chain mail[2]. The curved edge can be used to hook around the enemy's ankle, neck, or even shield to force them into a direction that provides advantage. The pointed end can be used for stabbing and slashing as well.

Today, axes are typically created using different steel alloys, containing distinct mixtures of iron and carbon. Percent carbon is important, as it is a primary indicator of hardness. The steel strength may be increased in strength with Cobalt, Molybdenum, Phosphorus, and Silicon. Chromium, Copper, Nickel, and Vanadium help to reduce corrosion. Tungsten helps with the blade's durability and combats against wear. Some of the most used steels for creating exes include: Carbon Steel such as 1050 or 5160, or Stainless Steel, 400 series. Carbon Steel is harder than other steels, and is easier to sharpen, thus staying sharper longer. Medium carbon is used for its honing properties and heat treating properties. Stainless steel is used typically for resisting corrosion, and is generally more ductile.[3]

Methodology

Through the conceptualization phase, a few important factors influenced the initial design. The overall blade size and dimensioning are a reflection of later Viking times where crescent shaped heads with blade lengths of 9-18 inches where used.[2] Understanding that through this time period, axes used in battle rarely had designs, the concept model was representative of a more ceremonial axe head with mechanical properties exceeding those of a traditional battle ready axe. Integrating a robust axe head suitable for battle, with detail that mirrored its time period was of the utmost importance. Thus, Norse symbolism was used multiple times throughout the design. Tying all of the Norse symbology together is the sea serpent intertwined into the blade design symbols, as the vikings were seafaring raiders conquering the earth's waters, much like the majestic sea serpent.

The symbols used in the final design, not only fit in well from an aesthetic standpoint, but represent Norse characteristics and religious beliefs. The placement of the Valknut symbol was important with the bridge between the blade and handle symbolizing the life that holds it and the death it was certain to bring. Also, a form of Norse writing called Rune was used to integrate the University of Northern Iowa's name in the design. Fortunately, not only did it provide an opportunity to use UNI, the meanings associated with the Runes, again align with the perception of a Viking warrior. Listed below are the used symbols/runes and their meanings according to Norse-mythology.org:

 *The Valknut:* Is a symbol associated with the transition from life to death.

 *The Helm of Awe:* Is a symbol associated with protection and might.

 *U, Uruz (Rune Translation)*, Meaning: Strength of Will

 *N, Naudhiz (Rune Translation),* Meaning: Need, Unfulfilled desire

 *I, Eihwaz (Rune Translation),* Meaning: Strength, Stability

All the design detail was modeled to provide for optimal sand mold removal. Proper drafting and depths on the blade design were calculated to ensure the detail would remain through the casting process. The depth of the design was not only critical for maintaining its detail upon solidification, but it also provided enough material in between both designs to provide for a solid blade core. In theory, giving the axe blade increased material to harden upon heat treatment increased the overall integrity of the head for maintained functionality.

When designing the gating there are multiple factors that need to be considered. These factors consist of: each alloy's different pouring properties, where defects are most likely to occur, pouring temperature, and the wall thickness necessary to show the fine details in the casting. The initial designs were finished before a definite alloy was chosen, leading the gating

design process to be simulated for a worst case scenario. A low carbon steel was used in the initial simulations to avoid delays from choosing the alloy. Low carbon steels would be considered the worst case scenario, specifically related to shrinkage defects, causing porosity, when using solidification software. This allows the rigging system designed for low carbon steel to be adapted for optimal filling later on in the chosen alloy.

After finishing the gating system calculations, it was modeled in Solidworks to import the gating system along with the casting into Magma. Before the simulations, it had been decided to part the mold horizontally. Chills were placed in the drag and the metal reservoir resided in the cope. The chills in the drag idea was to have a microstructure with tighter grains is for increase hardness at the blade, due to the quick directional solidification. The percolator on the other hand is meant for two reasons. The first is to allow flow of unwanted slag and sand that might be in the initial flow. The second, is to act like a chamber to collect gas from the flowing metal, resulting in reduced gas defects. This causes the pattern to have a very large gate, along with a gating ratio of 1:3:3. The extremely large gate added a challenge to de-gating the axe.

The molds used an ester cured phenolic binder system, for its high thermal strength properties. At room temperature, an ester cured phenolic binder has less strength when compared to a phenolic urethane binder. However, when the ester cured phenolic binder system is heated, it becomes significantly stronger than the phenolic urethane binder. Phenolic ester helped to keep the details, by resisting the heat of the steel during pouring. There were numerous thin features that would erode away if the binder was not strong enough to withstand.

The finished molds were brought to Viking Pump Alloy foundry. The molds were placed together using locators to ensure everything was lined up. 5160 steel was the alloy chosen to

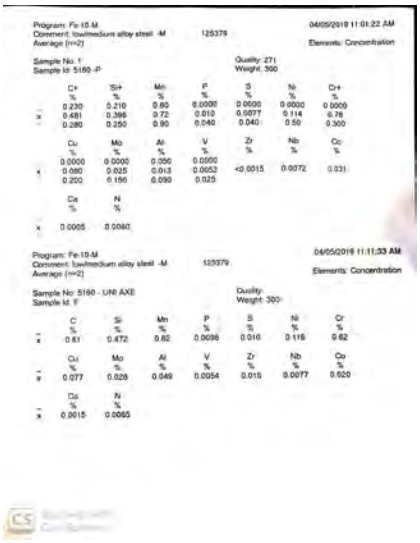
work with because of its hardness and durability. The as cast condition has a hardness that makes it unnecessary to preform heat treatments, as there is already a significant hardness. While pouring, an argon gas cover was used. This allowed for a cleaner melt and to increase the life of their lining. Three-hundred pounds of 5160 steel was melted. Four viking axe molds, each requiring 40 lbs of metal were poured. After completing the blocking treatment, aluminum and zirconium were used for deoxidation. Ne defects were observed in the castings after shakeout.

When making the handle, there were multiple things to consider. These factors include the type of wood being used, the shape of the handle, the length of the handle, and how to secure the axe head to the handle. The handle was going to be made for functional purposes, so the most practical options included oak, hickory, ash, or walnut.[4] From those options the team decided on ash due to the look of the wood when putting on the axe head, the strength of the material, and the cost and availability of the wood. A little bit of curvature was added to the shape of the handle, for easier wielding of the axe. Traditionally, Viking axe handles are straight but there are some that are curved to meet the needs of the owner. The length of the handle was determined by the swing the owner needs to take, in order for the axe to function[5]. The handle was fitted onto the axe head through the use of wedges. The top of the handle had a slit cut open for a wooden wedge to be placed into, in order to secure the axe head to the handle. To secure the wooden wedge, two metal wedges were placed to make a cross with the wooden wedge.

Results

- The castings were measured to have a Rockwell C hardness of 27.
- All four axe castings were poured without any defects.

- Figure 1, shows the Chemistry of the alloy poured.



Program: Fe-10-M
Comment: low/medium alloy steel -M
Average (n=2)
125379
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Elements: Concentration

Sample No. 1
Sample Id: 5160 -P
Quality: 271
Weight: 390

	C+ %	Si+ %	Mn %	P %	S %	Ni %	C+ %
x̄	0.230	0.210	0.85	0.0095	0.0000	0.0000	0.0009
	0.481	0.396	0.72	0.010	0.0077	0.114	6.76
	0.280	0.250	0.90	0.040	0.040	0.50	0.300

	Cu %	Mo %	Al %	V %	Zr %	Nb %	Co %
	0.0000	0.0000	0.056	0.0000			
x̄	0.080	0.025	0.013	0.0052	<0.0015	0.0072	0.031
	0.200	0.150	0.090	0.025			

	Ca %	N %
x̄	0.0005	0.0080

Program: Fe-10-M
Comment: low/medium alloy steel -M
Average (n=2)
125379
04/05/2019 11:11:33 AM
Elements: Concentration

Sample No: 5160 - UNI AXE
Sample Id: 9
Quality:
Weight: 390

	C %	Si %	Mn %	P %	S %	Ni %	Cr %
x̄	0.61	0.472	0.82	0.0096	0.010	0.116	0.62

	Cu %	Mo %	Al %	V %	Zr %	Nb %	Co %
x̄	0.077	0.028	0.049	0.0054	0.015	0.0077	0.020

	Ca %	N %
x̄	0.0015	0.0065

Figure 1: Chemistry of the Heat

- Figure 2 shows finished axe.

Figure 2: The Finished Axe

Conclusion

The Axe was a tool used by all during the Viking era. We reproduced a chromium medium carbon steel ceremonial blade through the use of a Phenolic Esther binder system and the help of Viking Pump and their argon filled ladles. This axe represents the University of Northern Iowa as well as the Vikings through its decorative ruins. The team learned about norse mythology, casting design, pattern and mold creation, finishing and sharpening techniques, and project management.

Acknowledgements

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Appendix

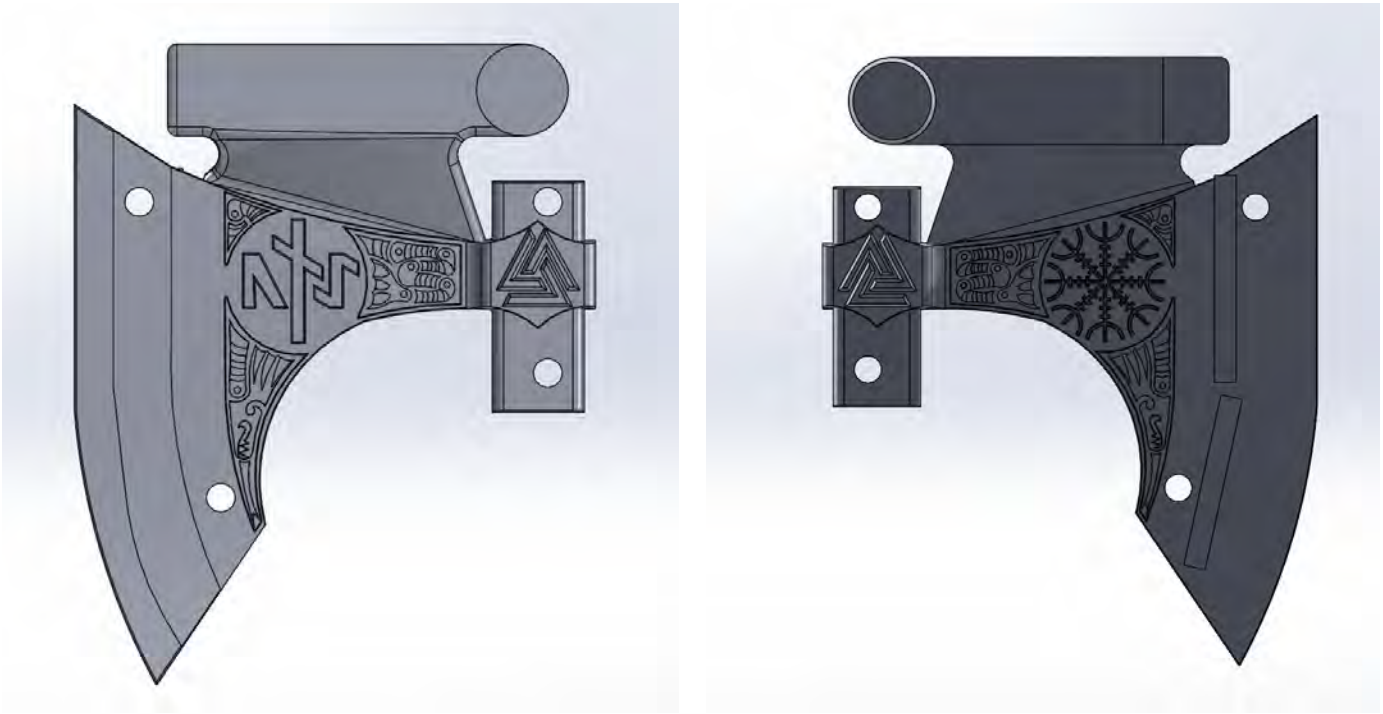

Fig. 3. Design of Viking Axe

Figure 4. Molds made from the patterns.

Figure 5. The molds coated with a high solid zircon coating.

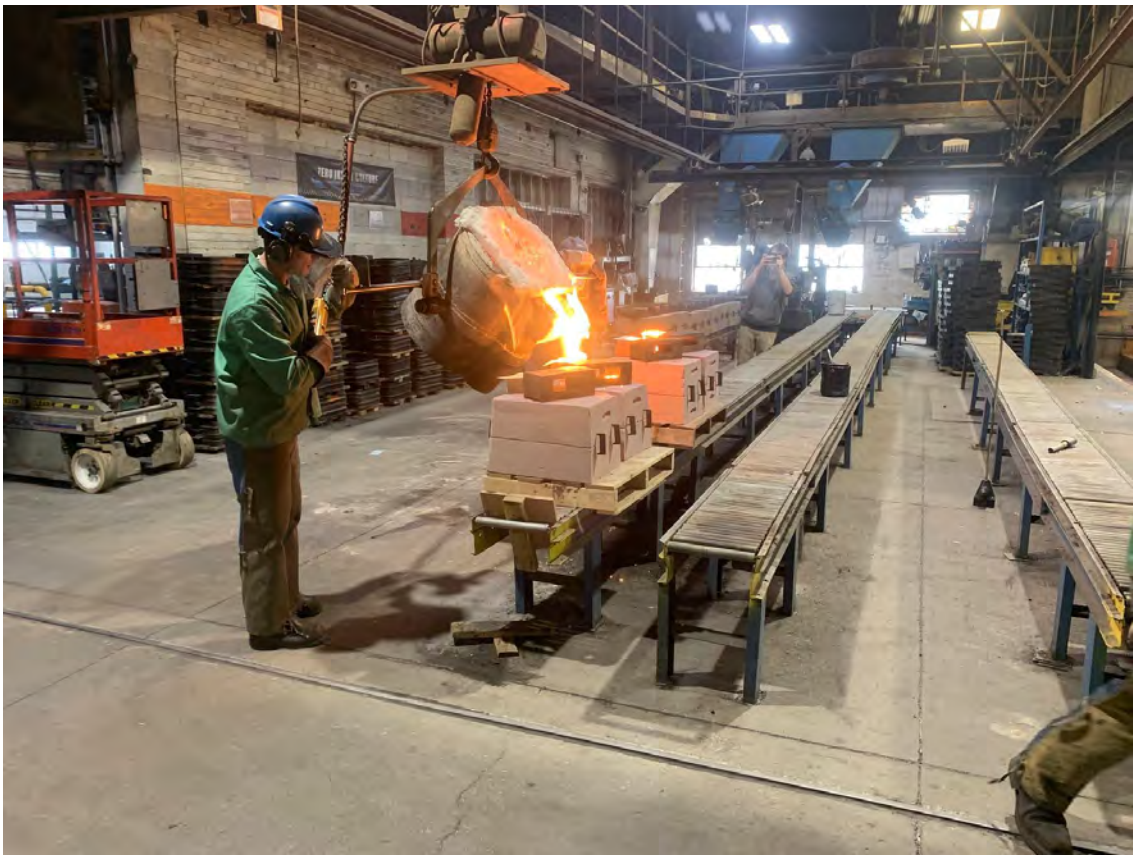

Figure 6. The pouring of the Axe heads.