Cast in Steel
Viking Axe

Youngstown State University - American Foundry Society

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Design & Engineered Geometry

For the design of our axe, we first read through the article provided by the SFSA (Hurstwic Viking Axe). After becoming familiar with some traditional Nordic styles, shapes and general techniques used in axe making, we looked to the web for further design inspiration. We found a web page titled "Two-handed axes", written by Tomáš Vlasatý. From the second image on the page, titled "Petersen's axe typology", our team decide that "Type D" was similar to a final shape that we could peruse.

Our next step was to research the actual physics-based design of an axe. For this information, "The Axe Book," by Gränsfors Bruks, "An Ax to Grind," by the United States Department of Agriculture, and "Design Manual on Basic Wood Harvesting Technology," by Food and Agriculture Organizations of the United Nations were all referenced for basic axe geometry, specific blade sharpening, as well as handle design.

For the first stage of the design process, a handle shape was determined and drawn in SolidWorks. Our handle shape was determined from information on pages 17-20 of "An Ax to Grind" as well as pages 1-4 of "…Basic Wood Harvesting Technology." Even more critical information was obtained from "Keeping Warm with an Axe," by Dudley Cook. With the information gathered from these resources, as well as the competition guidelines, a 28" handle was chosen to use with our Viking axe design.

With the general handle shape in mind, we finalized our axe head design. The final design of the head and handle were done simultaneously in SolidWorks so that the center of gravity in each component and the complete assembly could be referenced for proper weight distribution. The "axis of lateral pivot" and "real axis of pivot" were dynamically drawn in so that they would move with the design as it come to completion.

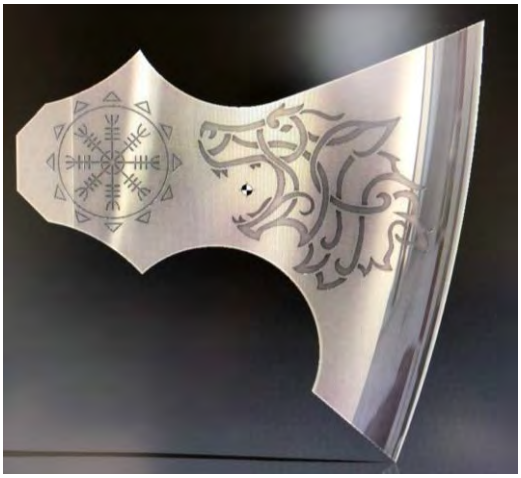


Figure 1 - SolidWorks Model of the Axe Head

The final shape of our axe takes into consideration; close combat, with the head cut away at the top to allow room for a very high grip on the handle; large, full power swings in which the curved handle near doubles the "fore-selection" as described in "Keeping Warm with an Axe." Essentially, the curved handle moves the pivot point 'behind' the axe head, allowing for more tangential force when the axe strikes its target. The large cut-out between the blade and the handle can also be used as a hook, to not only reach out and grab onto natural objects, such as boat docks, or trees, but also can be used to hook an enemy's legs or arms in combat. An 8" linear blade length was chosen. This was the perfect size for the axe to be versatile. Ideally, an axe head less than 4 pounds would be the more efficient while not being extremely light, but also not too heavy. This weight is ideal for close combat as well as wood harvesting and heavier tasks. The blade profile was taken from page 6 of "…Basic Wood Harvesting Technology." A softwood blade profile was chosen for our finishing method, as this seems the most versatile, considering combat and technical use.

With all things previously mentioned taken into consideration, and the use of a dynamic model in SolidWorks, our final handle and head shape were chosen. The finished product is an axe that is well balanced, versatile in combat techniques as well as wood chopping and hammering (using the poll, or butt of the axe head), and very ergonomic to hold and use, taking full advantage of the available geometry and physics that can be applied to such a tool.

Nordic Symbols

Since the creation of Sol and Mani (the sun and the moon), two twin wolves, Skol and Hati, began their hunt to catch pray. Eventually, when they catch their prey, the world plunges into darkness and triggering Ragnarok. While wolves are not usually seen as evil in Norse mythology because it is the nature of the wolf to hunt, it just so happens that their pray is essential to life on earth. The team decided to use the story of these wolves as the inspiration for our axe because the wolves embody the aspect of freedom and the outdoors. In many other cultures around the world including Norse wolves were seen as a symbol of danger, making it the symbol of the warrior also which works perfectly for our axe design.

In addition to the story, several other symbols were added to the axe to enhance the meaning. The Helm of Awe stands as a symbol of protection and might, which follows the wolves as they make their hunt. Also, The Svefnthorn appears between the wolf and the moon to symbolize the long, deep sleep that would occur when the wolves caught their prey.

Material

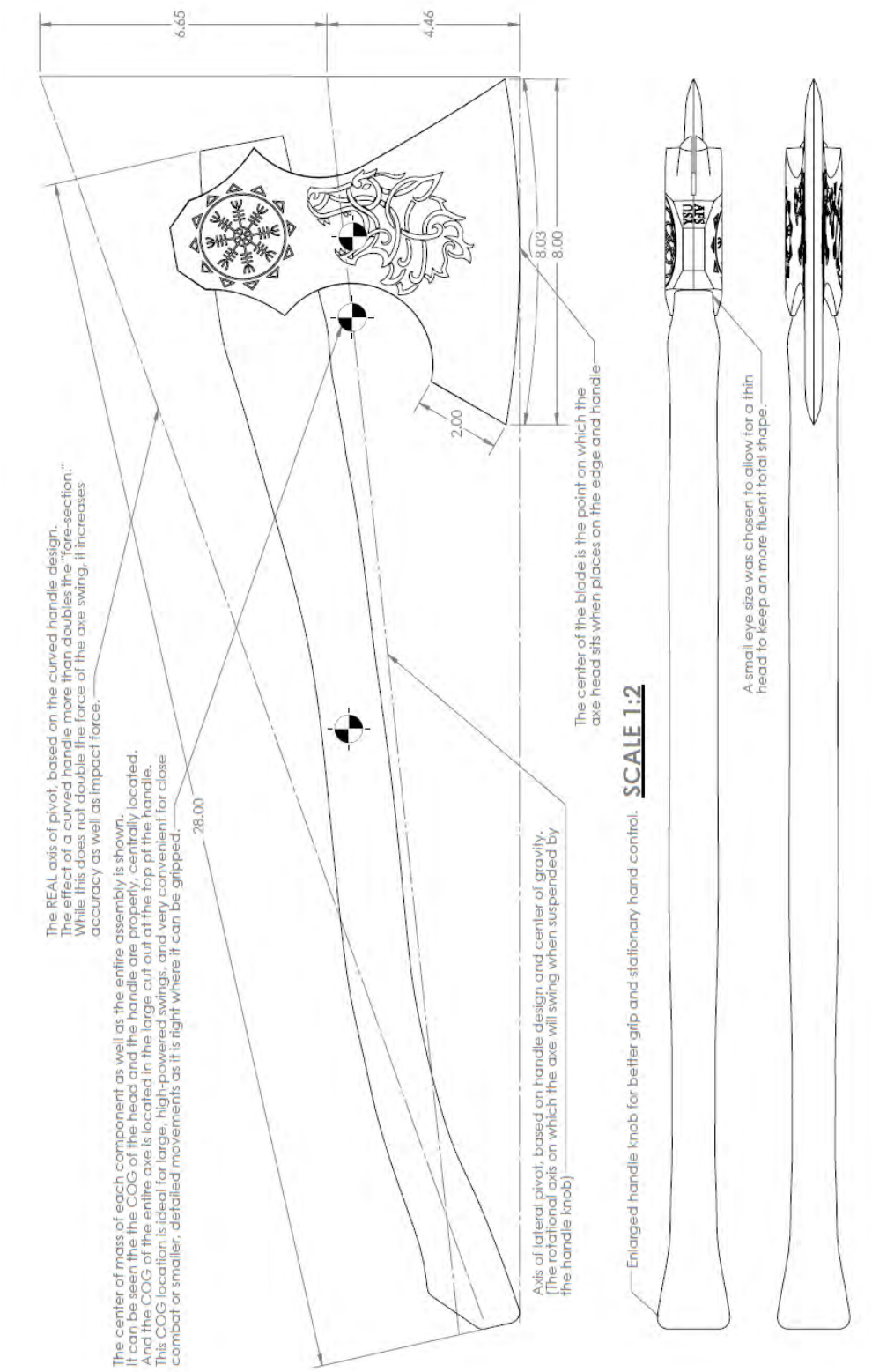
We selected 6150 Cast Steel for our axe. We chose this alloy because it has a high tensile strength and toughness. The 6150 alloy is similar to 5150, however with the addition of vanadium it also gives it a higher hardness rating. Our alloy also has low distortion properties, which we believe will help the axe head to retain its edge. This material is commonly used in automotive applications such as gear and engine construction. We believe this alloy, after our heat treat should have an HRC of around 42.

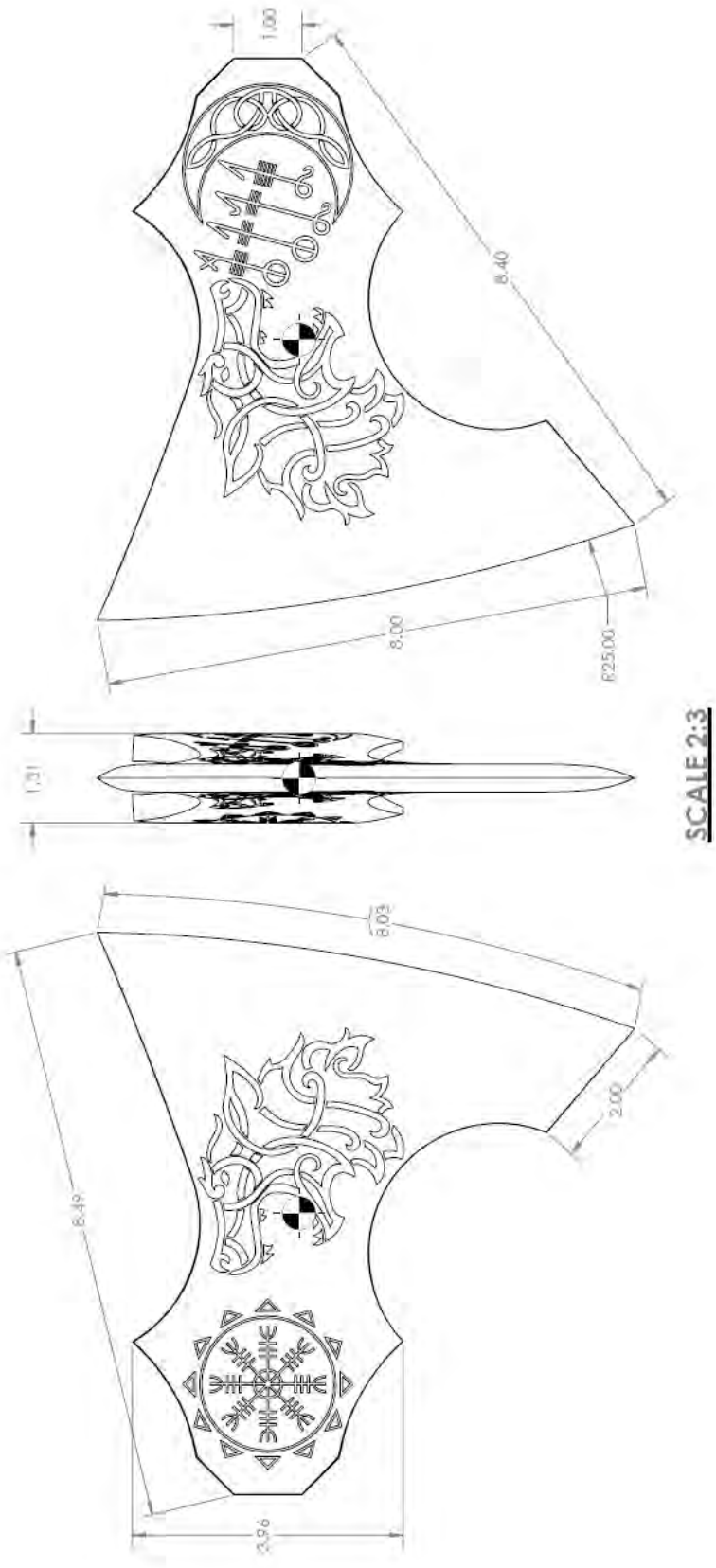
In order to strength our material, we used several processes to treat our axe. The first process used was a normalization for one hour at 870°C, which was air cooled. We then reheated the axe to 860°C for one and a half hours, then oil quenched to cool. Lastly, the axe was tempered to 450°C for two hours, then air cooled.

Mold Design and Casting

Once, the material and final axe design were chosen, the mold was designed and run through MAGMA to ensure that the mold would produce a good casting. After getting a successful simulation, the axe head was 3D printed on Prusa printers and taken to Greenbriar Pattern Shop. At the shop, we packed several molds using the 3D printed axe and air-set sand. The molds were then taken to Trumbull Metals, where the axes were cast.

Axe Geometry Drawings

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Photographs of the Casting and Axe

Figures 2 & 3 - Team members assembling the mold.

Figure 4 - Steel cooling inside of the mold.

Figure 5- The axe cooling in half of the mold.

Figure 6 - Axe heads after the gating was removed.

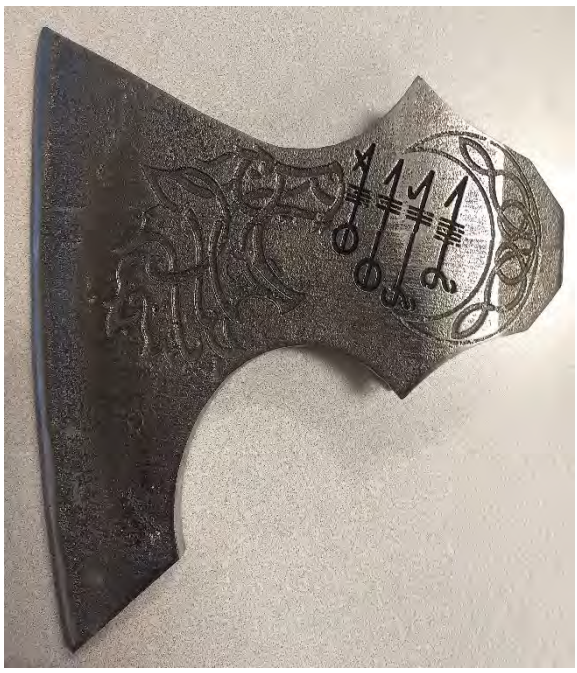

Figure 7 - Axe head after being cleaned.

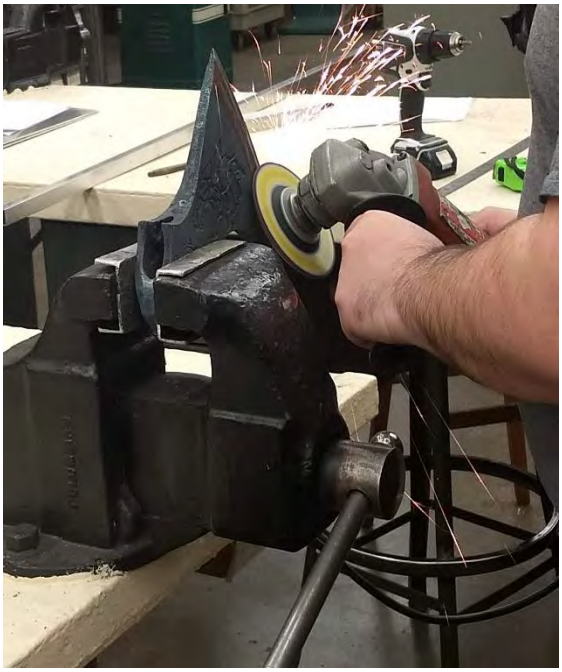

Figure 8 - Grinding to adjust the blade's taper.

Figure 9 - Normalization of the axe.

Figure 10 & 11 - Finished Axe

Acknowledgements

The YSU team would like to thank our foundry partner, Corey Jarvis (Trumbull Metals), for his help throughout the project. Also, Kevin Dean (Greenbriar Pattern) for helping us make the mold patterns, and Brian Vuksanovich for his help and expertise with heat treating.

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