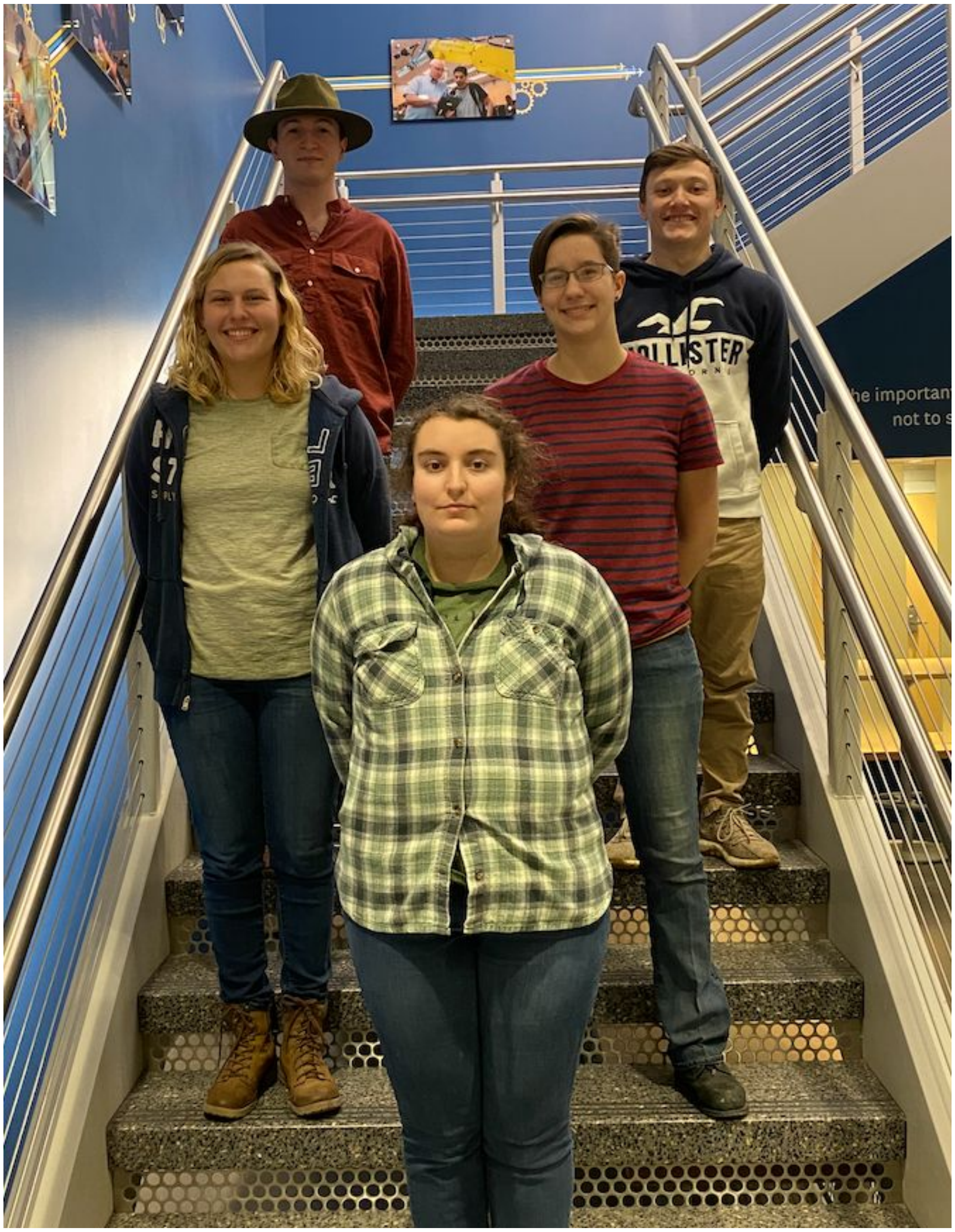
STEEL FOUNDERS' SOCIETY OF AMERICA

KENT STATE UNIVERSITY

Cast In Steel 2021

Stormbreaker Team



Kent State University - Stormbreaker Team
Front row: Team Lead Samantha Battaglia
Middle row: Alissa Sarver (left) Sarah Kuntzman (right)
Back row: Aubrey Heald (left) Nicholas Jones (right)

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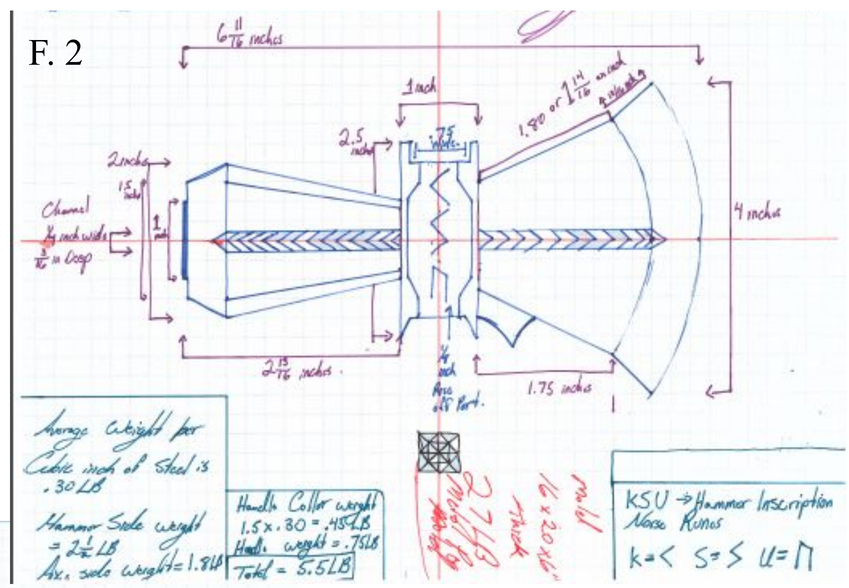
Drafting Concept

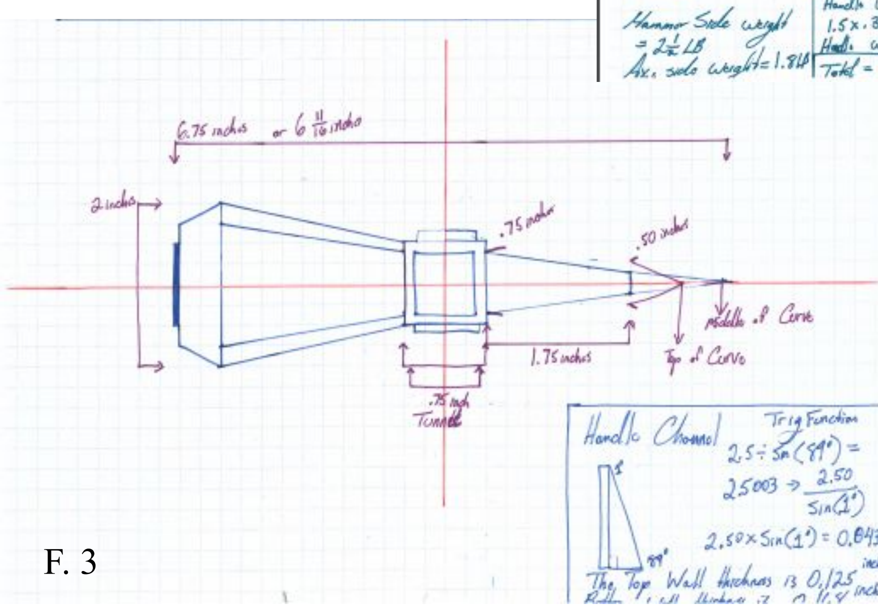
Our submission is based on Thor's hammer Stormbreaker as shown in Figure 1.

The sketches were started with the knowledge of steel's cubic density which is 0.30 LB per cubic inch. The competition specification stated that our part with handle couldn't weigh more than 6 lbs. This helped us to draw a roughly scaled rendering of the part on graph paper as shown in Figures 2-4 . Several different views of the part were drafted to show all sides of the part. The decision was made to make a braided rope pattern on the hammer face itself which would really tie in the origins of the part and link it nicely to Norse mythology which is where the story of Thor comes from.

F. 1

F. 2

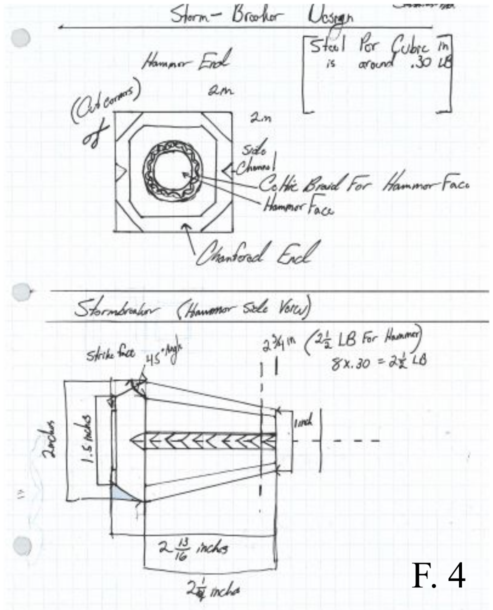




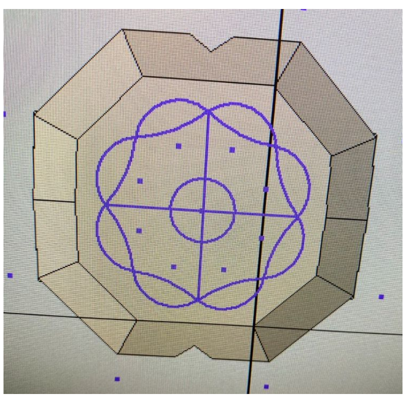
F. 3

Drafting Concept

To achieve the best size for our hammer face's pattern we sketched several different designs. The initial design is shown in figure 4 and our final design is shown in figure 5.. This was done so it would cast cleanly, and be strong enough to not incur damage with use. The design changed a few times due to size and density issues to ensure that it was still within the specifications given by SFSA throughout the design process. In figure 6 you can see our rough dimensions. These helped throughout the design phase to find an estimation of the parts overall weight. Once it was 3D modeled calculations were much easier to achieve in regards to the weight since the program allowed for material type selection. The initial design was created based on the competition guidelines stated that each team can do any of Thor's hammers from any depiction throughout history and base a design off of personal interpretation .



F. 4



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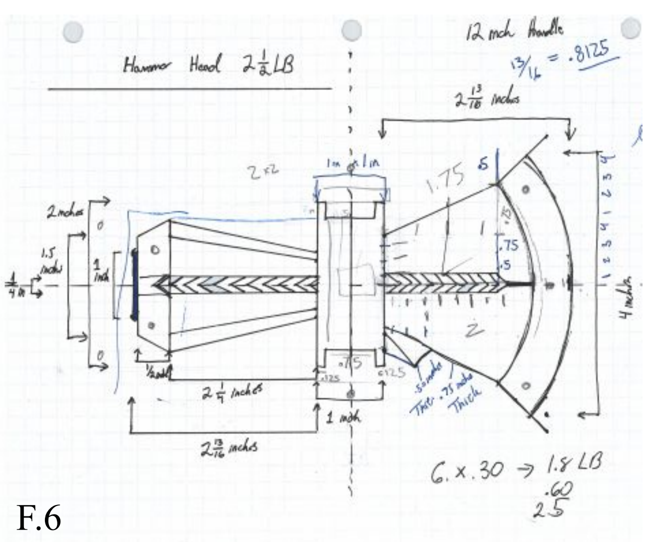

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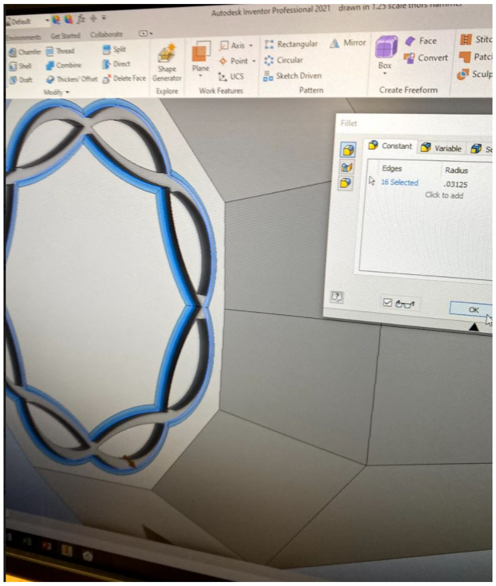
3D Design



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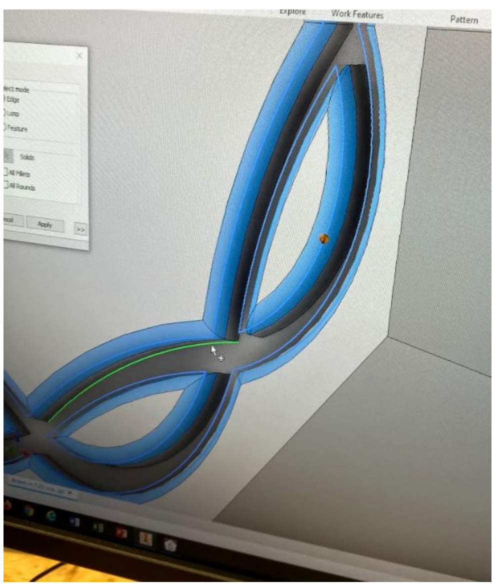

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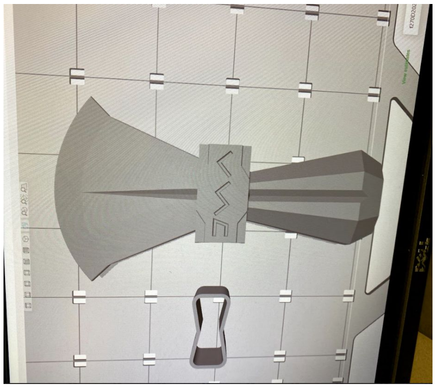
With the completion of the overall drafting done we also had to make sure that we designed our part to house the handle once it was shaken out of the sand we did this by modeling a sand core for the handle cavity. This would leave very little work to mount the handle once the part was cast.

We went through several versions of our hammer face pattern due to size and intricacy issues. Our initial pattern was a three strand braid, but the size of the extruded lines were too fine and would have caused the pattern to be too difficult to cast and too small to withstand normal wear and tear. Once the drawings were done they were recreated in Autocad to start designing on the computer as seen in Figure 7 & 8. Once we had our pattern finalized we then went and filleted the channels to smooth out the angles and make it more castable. We also had to make sure that when we extruded the knot work design it was deep enough to allow us to crown the hammer face without losing the design. Our first design was too small to be clearly cast or machined into a pattern so we had to adjust for this.

3D Modeling



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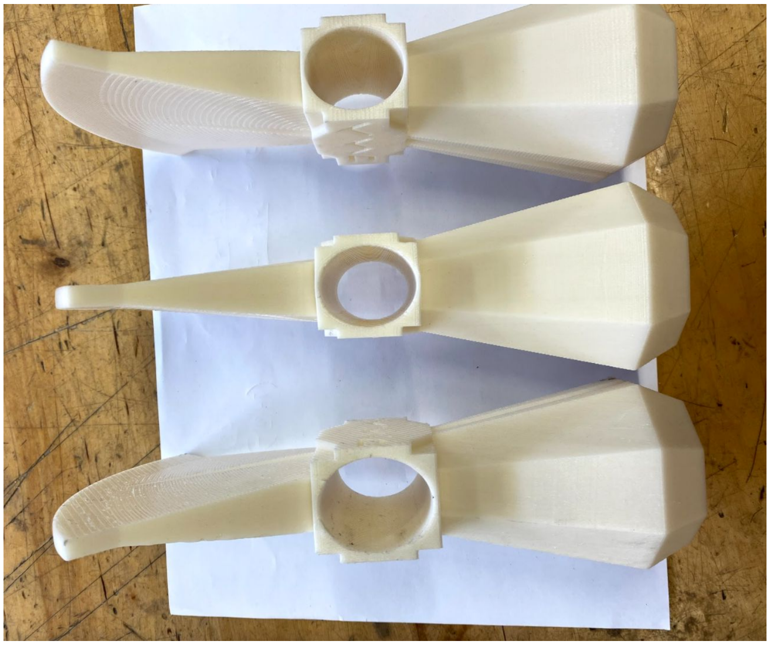
Using a Stratasys F270 3D printer we printed out four different renditions of our part in ABS. Each version slightly adjusted for projected weight and size of around 5 lbs. This allowed us to get a better physical feel for the size and shape of our part. Once the parts came out of the printer they went into a bath of heated chemicals to dissolve the support material used to create the cavity for the handle as shown in figures 9-12 Once the process done we took them out to dry and then tested the fit of the handle and measured the overall width and length to adhere to the competition specification to make sure our part was under. We used trigonometry to adjust the internal taper of the housing for the handle to ensure a good fit.This process also helped us to understand the limitations we faced with theknot work design that we wanted. We saw with the first print that the initial design was too small to be functional. Once we figured out the knot work pattern we did a final rapid prototype.

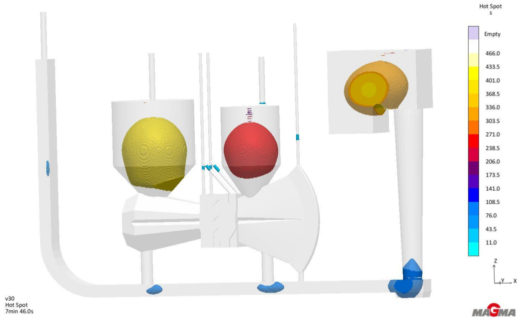
3D modeling



F.13

Figure 13 shows the different part sizes that we printed throughout our design process. The initial rapid prototype shown at the top of the picture shows that the handle hole was too small and the hammer's face pattern was deemed inappropriate for casting. The second part in the picture has a corrected hammer pattern, but the handle housing was not right just yet. Finally we found the best design which is displayed at the bottom of the photo which has a reinforced handle housing and finalized hammer and axe components.

MAGMASOFT



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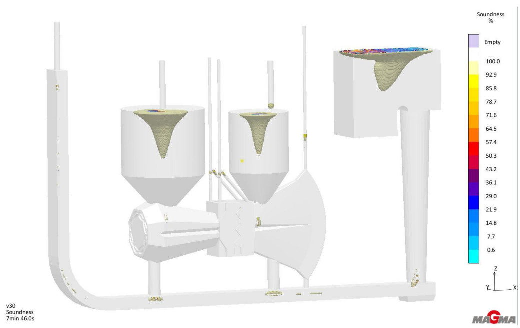

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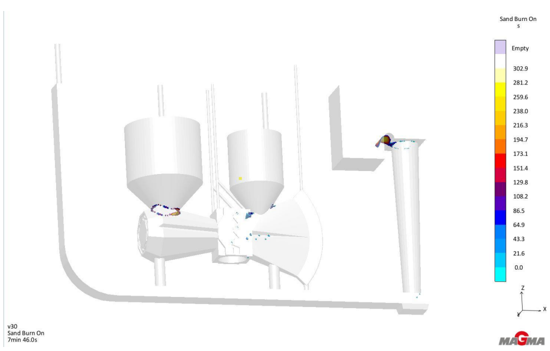

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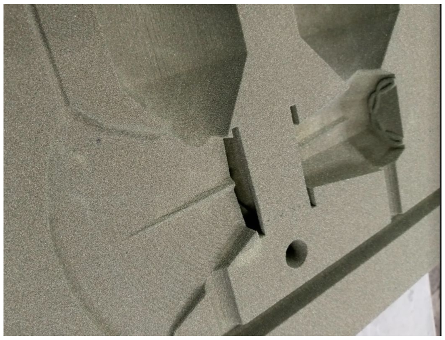
MAGMASOFT software was used to simulate the filling of our mold designs to check for defects before we ordered physical molds to cast our part. In total, we ran 30 simulations to perfect our gating and riser design for our final application. In each iteration we were looking at the fractional liquid results and soundness results with a goal of removing all chills and bringing the mass of the hotspot out of our casting and placing it in the middle of the riser as seen in Figure 14. Porosity results as seen in Figure 15 show no major defects within the casting area and expected porosity within the feeding system. An additional concern was sand burn on due to the use of 3D printed sand molds and not being able to control the density of the sand around the risers. As shown in Figure 16, the predicted occurrence of burn on is low and confined to the riser casting interface. Figure 17 shows the casting at the shake out where we happily found no burn on in the area of initial concern.

3D Printed Chemically Bonded Sand



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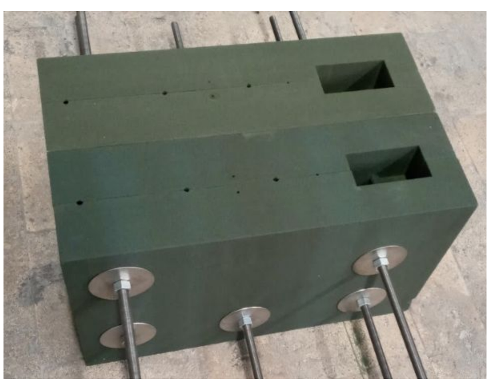

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We created 3D model files using Autodesk inventor. The model files were used to create the mold. It was decided that the best way for the molds to come out was by using a vertically parted mold. Once the files were done then the files could be sent off to be 3D printed in sand. The sand molds were printed by Humtown Products in Leetonia, Ohio.

Humtown specializes in the printing of 3D chemically bonded sand molds. Six molds were ordered from them so we could make several copies of our part and send out the best one to the competition. When the molds arrived they were cleaned of all the loose sand within each mold half and then compressed air was blown through the vents to ensure they were all open. Once they were cleaned they were placed on the floor of our pouring deck, where they were aligned and bolted together for pouring. On the initial pour we tried to use ceramic stopper rods in the pouring basin which were donated to us by Industrial Ceramic Products. The function of the ceramic stopper rods was to stop the metal from entering the mold until the pouring basin was filled so that the air would be pushed out reducing air related defects.

Casting in Chemically Bonded Sand

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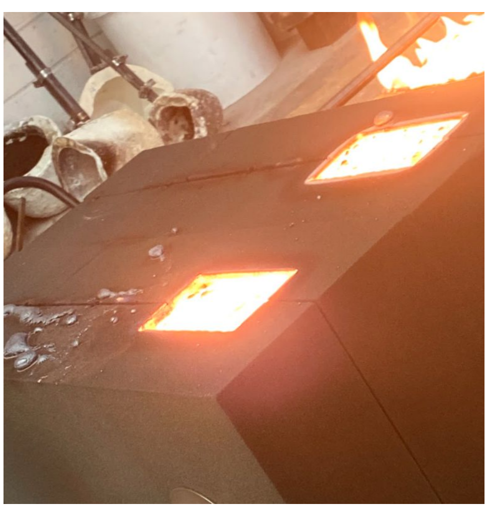
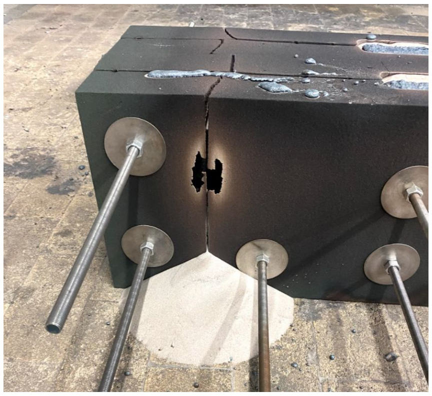


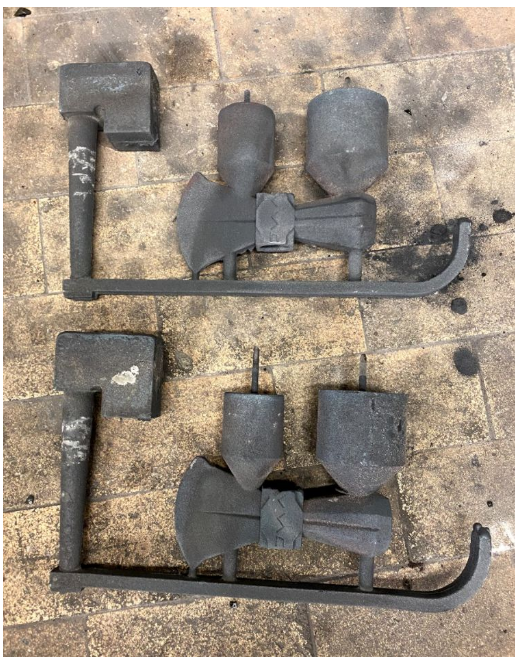
F.24

Upon the initial 3D simulations there was a good deal of turbulence and through the research that was done it was found that the use of a stopper rod would reduce turbulence which in turn would help eliminate air bubbles and related defects This would also have helped to reduce to likelihood of a bi-film from forming within the part. When using the stopper rods it was found that they absorbed too much heat from the liquid metal when poured causing the metal to solidify and the ceramic to fracture in the mold, which caused the first two molds not to fill past the pouring basin. For the second pour our team elected not to use the stopper rods because they needed to be heated before casting to reduce drastic temperature drop in the liquid metal itself.

Casting



F.25



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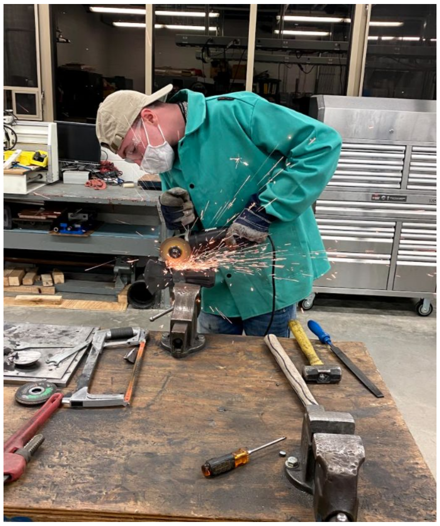
F.27

During the second attempt two complete castings were made. Once the castings were cooled excess sand was knocked away from the rest of the part, which was weighed the part came to 27 lb. This was well within the projected weight of 30 lb After pouring. The next step was to saw off the gating system and the risers to begin the finishing work.

This round of casting yielded two usable parts which filled nicely and only had small spots where they needed some mig welds due to air pockets. These air pockets were likely due to clogged vents, upon visual inspection we noticed these clogs within the vents. It was found that they were filled with unbonded sand which didn't allow air to escape quickly from the mold and caused cavities where air took the place of metal. This discovery was found with the use of a small piece of metal wire, which was unable to move freely along the vents, indicating a blockage creating these defects.

Finishing



F.28

F.29

With these two castings the team dedicated one for process testing and the other to be our final product. With this in mind the next stage began with finishing work which starting by removing the gating system with a horizontal bandsaw.

With the gating system removed the next step was to start grinding away the remaining sections of risers. Once the grinding was completed the casting moved to the belt sander and began to rework the surface of the part until it was smooth. This was done to remove the indentation left on the surface of our casting from the mold. However the axe blade was left untouched because the texture from the 3D printed sand mold left a really interesting aesthetic on the metal surface which added to the value of our casting. When the mold halves were printed some of the halves were vertical and some were horizontal. This can be identified by the layer shift. If the mold was horizontal then the casting was left with circular ring as opposed to the vertical halves the pattern could not be seen. The team also wanted to give the casting a nice surface finish and leave all the recessed details rough so there would be a good visual contrast. This meant that our hammer face's pattern would pop and the Norse runes on the side of the hammer which spell out KSU (Kent State University) would have high visibility and clearity.

Finishing

F.30

F.31

F.32

Throughout the sanding process the main focus was on the angle of approach used while working the part in orders to achieve flat even planes across each face. This meant spending several hours to sand and polish 27 faces on the part which is demonstrated in figures 30 -32. While sanding occurred the surface was worked over with various grits of sanding belts in order to achieve a nice surface finish. When we got to section that need more attention to detail we started working with a smaller sander in order to produce a uniform surface to the whole part.

Finishing

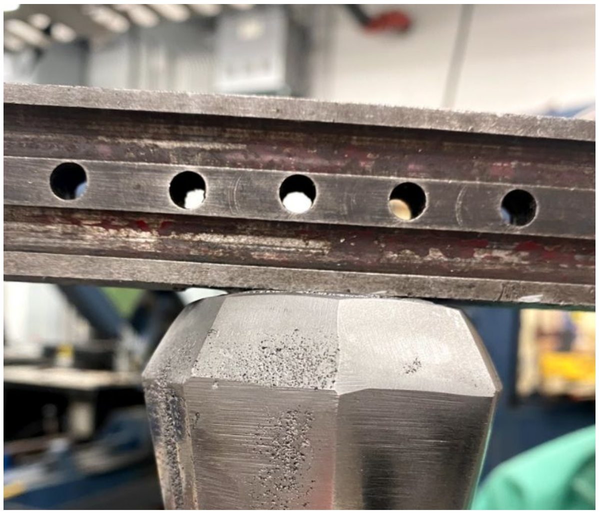
F.33

F.34

F.35

Once the surface work was mostly completed work was started on the axe's cutting edge. The belt sanders platform was at a 30 degree angle to do the edge of the axe blade. It was set up that way because a 60 degree angle is a standard measure for an axe blade. Once the axe was done it was mounted with wooden slats to protect the blade and placed it into a rotating vise which was connected to a cordless drill. This unique setup allowed for the crowning of the hammer to be done with uniformity and precision. To achieve this one student used an air powered sander working in a single direction going back and forth at an angle while another student used the drill to rotate the vise 360 degree. This allowed us to sand down the crown while rotating the casting to achieve a uniform crown.

Hammer Face Crowning



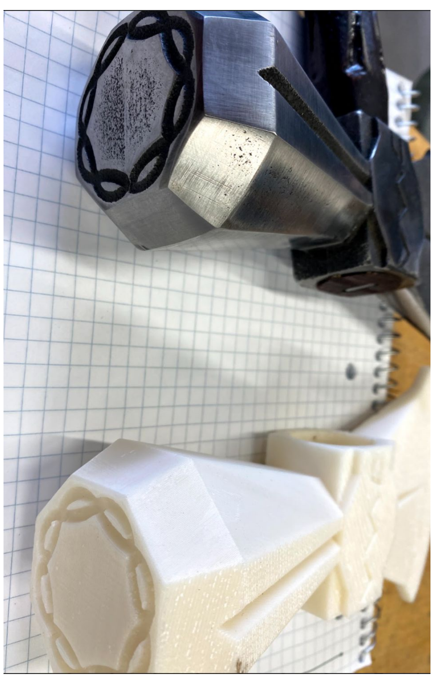
F.36

Once the crowning of the hammer was finished a machinists parallel was used to check the curvature of the hammer after sanding. This can be seen in figure 36 where the edges of the parallel have gaps on either side where material has been sanded away from the part.

Crowing the hammer will ensure that when it is used full contact can be achieved at several angles along the surface of the hammers face. This will reduce the likelihood of the hammer skipping off an object when it is struck. The hammer side is a bit softer than the axe to ensure that it can be used without chipping or deforming.

Casting – Pattern Molding

F.37



F.38

Once the part was cast an initial comparison of the hammers were made to see how the pattern came out compared to the 3D printed version as shown in figure 37 & 38. There was a small amount of flashing within the channels of the design but they were very small. Figure 37 & 38 also showcases the integrity of the finalized design which has to go through sanding and polishing without losing the knot work design. This design also demonstrates the proper clearity in the casting which was planned and well thought out. Accounting for the shrinkage in the metal as it cools was a big reason to make such a large design for the hammer face. The use of the initial hammer face design would not have been visible as the size and intricacy were too small and complex.

Heat Treating

Upon the completion of both hammers a final cleaning was done to them and then the forge was fired up to heat treat them just enough to strengthen and harden the axe. This happened by heating up the axe and then quickly cooling it to restructure to crystals within the metal to make them form fine and tightly packed grain boundaries within the metal. Once they were placed into the forge they stayed there until the edge of the axe began to draw in a nice glow. Then the casting went right into the quench. This was done by only submerging the axe blade for around 20 second then the whole hammer was submerged allowing the entire part to completely cool in the oil overnight.

F.39

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F.41

F.42

Handle Fabrication

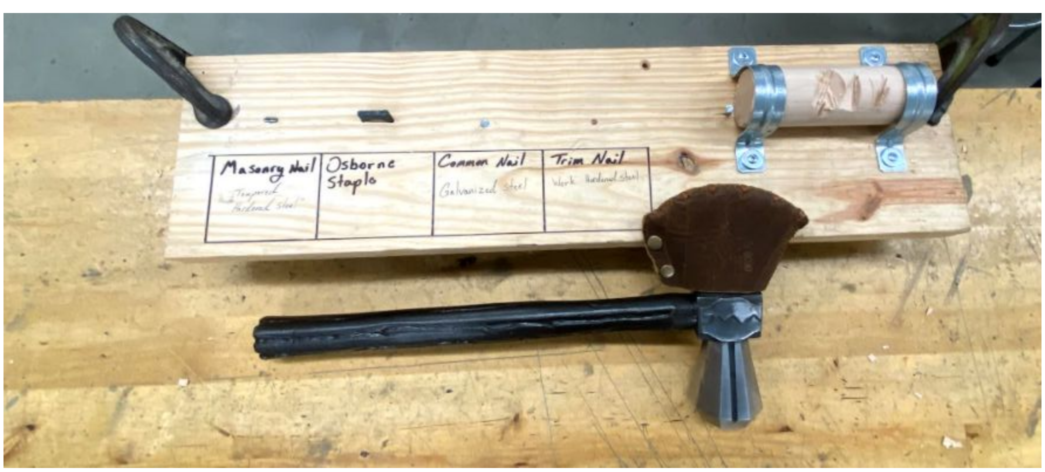
F.43

For our handle the decision was made to tie the handle to the cinematic version. In the cinematic version where stormbreaker is first shown Groot who is a tree creates the handle so that the axe and the hammer weld together and become one. Groot achieved this by using his fingers to grab the two halves and smash them together. Finally he grew his arm out to form a long handle when the length was achieved he severed his arm which created an intact hammer. To model the cinematic versions handle a dremel was used to carve in channels down the handle to make it look more like a natural tree branch. Doing this small detail connects it to the film where the handle is made from an unprocessed tree branch. After carving was completed we ran some 330 grit sandpaper along the handle to smooth that wood out for staining. We used a nice dark Kona stain which was applied in two layers. After the stain was done and lacquer was applied allowed to dry we then scrubbed with a Brillo pad to rough the surface up and dull the shine. Once this was all done the handle was lightly sanded to make sure the lacquer was not too slippery.

F.44

Hammer testing

Once the hammer had been mounted to the handel the decision was made to make sheath to protect the blade and the user. After the sheath was made testing on the hammer could begin,This decision was made in order to protect the user from accidentally getting cut. For testing we mounted a 2” dowel to a 2x6 and then set up 3 types of nails and an industrial staple. For test 1, we started with a carpet trim nails which are hardened steel. This test yielded no deformation on the hammer face. Test 2 was a common nail. This went in very smoothly and left no marks. Test 3 was an osborne staple which was a ¼” thich. This left small scratches on the hammer face, but nothing a light sanding couldn’t clean. Test 4 we used a masonry nail which is galvanized and hardened which left little to no marks. Test 5 was for the axe’s cutting ability to ensure that it didn’t chip of deform when chopping.



F.45

Team Finances

The budget for this project was supported by our student chapter of AFS. Since the Stormbreaker team was comprised of AFS students in the chapter. The student AFS chapter then voted and approved, to use their funds to support this project. This included covering the cost the molds which were discounted by Humtown to $70 a piece and we ordered six molds which was $420 with a delivery fee of $80. We made individual purchases along the way like the wood stain we used and the handles which we were reimbursed by the student chapter of AFS.

assortment of nails	$10
2*6 wooden board	$8
Video software purchase	$40 (indepent purchase)
Wooden handles	$63
Wood stain	$11
Chemically bonded sand molds	$500
Video software purchase	$35 (independent purchase)
½ * 12inches belts for handheld sanders	$104.64

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