Cast in Steel Competition 2021

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Abstract

The 2021 Steel Founders' Society of America's Cast in Steel Competition has given the participating teams the tasks of designing and casting a hammer that resembles Thor's hammer. Thor's hammer, named *Mjölnir*, is a one handed hammer wielded by Thor, the god of thunder in Norse mythology. Our team decided to make a representation of Thor's hammer based on pictures from video games' depictions of *Mjölnir* which follow design concepts from different amulets and pieces of jewelry found in historical evidence from Norse mythology. The head of the hammer was a composite design made in SolidWorks 2019 and it consists of a steel core component made of AISI 4130 steel, that provides the impact faces which are connected by a rod to a cylinder running perpendicular to them. The second component is the aluminum casing made of 1000 series aluminum which creates the physical form of the hammer while keeping it lightweight. This aluminum casing was cast after the steel and was poured around it; this allowed us to cover the structure which connects the two steel faces. These two materials are connected by grooves on the steel part that meet with the aluminum to make the head of the hammer.

The dimensions for the hammer head are 8.5 in from one impact face to the other, 4.74 in in height, and 3 in wide. The impact faces are 3 by 3 in squares. The head of the hammer was cast using sand molds which is what our foundry sponsor specializes in. The casting process consisted of the making of the steel part and then using the cooled and normalized steel part to place it inside of the mold for the aluminum. Once the aluminum was poured, the faces of the head were treated using the "rosebud" method which consisted of heating the faces up to about 900°F and then quenching in oil. We then took it to one of our members' houses and started working on getting the excess parts cut off; these parts included the gate system and the extra material that was in the risers. We then polished and painted it to make it look better which was followed by the making of the handle. The handle was made of hickory wood and it was shaped using a homemade lathe. The finished hammer had a length of 18 in and it weighed 5 lb, 11 oz.

Introduction

The Steel Founders' Society of America (SFSA) is once again hosting a competition for teams to create a unique tool that puts together different types of engineering principles while giving students the opportunity to work in the casting industry along with a partner foundry. This year's competition requires teams to create a replica of Thor's hammer.

The objectives and constraints given to this year's teams state that the hammer must have a maximum length of 20 in, weigh less than 6 lb, and must perform tasks that are typical of a hammer. It was recommended to either make the head hollow and/or use lattice structures for rigidness; we could also use a lighter metal to achieve the desired looks of the hammer while keeping the part of the head that receives the impact made of steel. The teams should prepare a video for the competition showing the process of making the hammer, a report that also documents the hammer making process, and we were given the liberty to choose any design for Thor's hammer as long as we were able to explain the reason why we chose a particular design for the hammer and why or how it resembles Thor's hammer [1].

History

In the polytheistic ancient Norse mythology, Thor was the god of thunder. He defended Asgard, the Norse equivalent to the Greeks' Mount Olympus, from giants, serpents, and other evil beings with his weapon of choice: the hammer. His hammer, *Mjölnir*, would always hit its mark when thrown and then return to him like a boomerang. The meaning of the name *Mjölnir* is disputed among historians. It has similarities to the Old Slavonic and Russian words for "lightning," the Old Norse word for "new snow," modern Icelandic for "white," or other Old Norse and Gothic words for "the grinder" [2, 3, 4].

Figure 1: A Thor’s hammer pendant [2].

Although primarily known as a weapon, *Mjölnir* was mostly a symbol of consecration and protection in the Old Norse religion that was used in weddings, funerals, and births even long after Christianity became the dominant religion among Scandinavians. It was also worn as a pendant, such as the one in Figure 1, by many as a ward against evil and violent forces, as well as to promote good health [4].

More recently, Thor is better known as a character in the Marvel comic books written by Stan Lee and Jack Kirby [5] and in the Marvel Cinematic Universe movies where he is played by Chris Hemworth. Thor first appeared in Marvel comics in 1962 and in the MCU in 2011. His recent film portrayal has popularized the Marvel version of Thor’s hammer and is what most people think of when someone talks about *Mjölnir*.

Design Ideas

1. Concepts

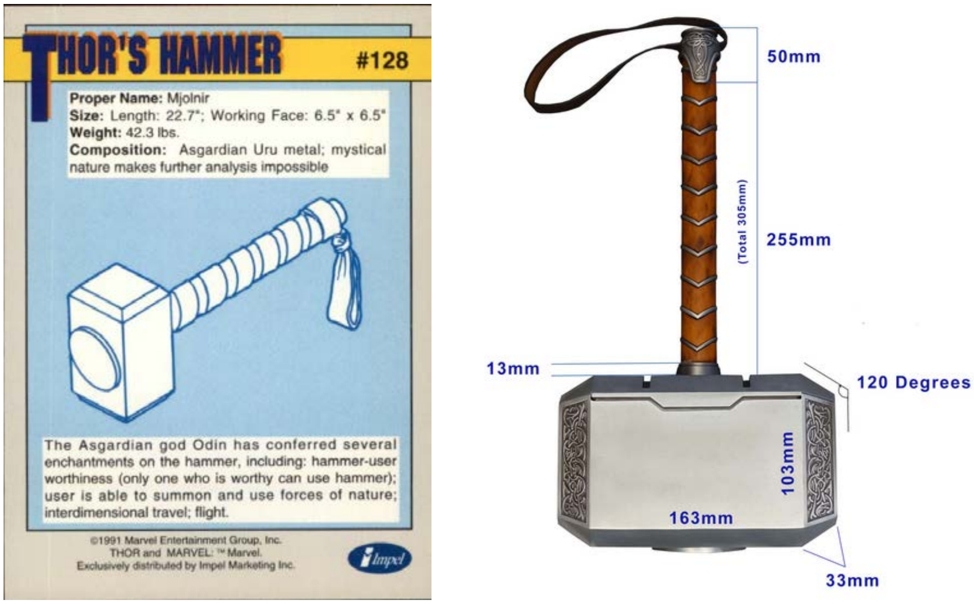
a. Mythological

Most depictions of *Mjölnir* found in the original mythology and in the artifacts left behind by the old Norse people are meant only as symbols of Thor's protection. However, these symbols, usually seen in the form of a small pendant worn around the neck, were not meant to be the exact form of the hammer itself. For this design, a lot of creative liberty would be required to make an actual, functional hammer that still maintains an appearance that invokes *Mjölnir*.

Figure 2: Recreations of *Mjölnir* as depicted in Old Norse Mythology (left [4], right [6]).

b. Marvel

In modern times, the first image many would have of Thor’s hammer would be the version popularized by Marvel’s comics and, more recently, their Marvel Cinematic Universe films. These versions both have a very well-defined physical form and set of dimensions. They also are not based very heavily on the Norse symbols of *Mjölnir*.



THOR'S HAMMER #128

Proper Name: Mjolnir
Size: Length: 22.7"; Working Face: 6.5" x 6.5"
Weight: 42.3 lbs.
Composition: Asgardian Uru metal; mystical nature makes further analysis impossible

The Asgardian god Odin has conferred several enchantments on the hammer, including: hammer-user worthiness (only one who is worthy can use hammer); user is able to summon and use forces of nature; interdimensional travel; flight.

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THOR and MARVEL: ™ Marvel.
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Figure 3: *Mjölnir* as depicted in the comics (left [7]) and films (right [8]).

While the comic books’ version was usually devoid of markings, the movies’ version has intricate markings on some of the faces, which are likely an homage to the markings found in many of the old Norse symbols, such as the one seen in Figure 2.

c. Video Games

Many different interpretations of *Mjölnir* have appeared in video games. Any game with references to Norse mythology or mythology in general is likely to have some reference to Thor and his hammer. A few of these video games include *Assassin’s Creed: Valhalla*, *God of War (2018)*, and *Valhall*.

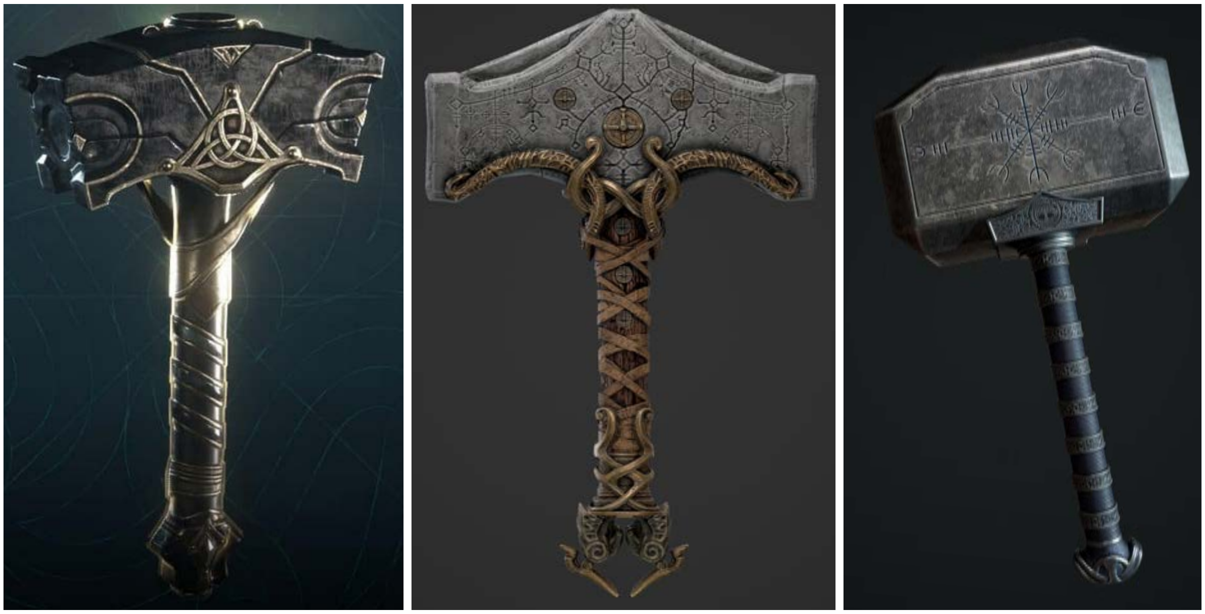


Figure 4: *Mjölnir* as depicted in the video games *Assassin's Creed: Valhalla* (left, [9]), *God of War (2018)* (middle, [10]), and *Valhall* (right, [11]).

All of these designs have a few things in common: grips consisting of small bands, intricate designs, and large square faces. They also share these features with Marvel Thor's on-screen hammer, so it is clear that these are all important aspects of *Mjölnir*'s appearance. While the *Valhall* design seems like it's heavily inspired by Marvel's design, the other two take inspiration from the original Norse symbols. The *Assassin's Creed* and *God of War* designs both have metallic design-work at the base of the handle like the one shown on the left of Figure 2.

2. Selected Design

Our first design was based on the comic book version, but after many iterations, sizing down, and different lattice structure ideas, the design was always over 6 pounds. Therefore, we decided to use the *God of War* design shown in the middle of Figure 4 and below in Figure 5. We made this decision because the design resembles the mythology while already having a defined form that we could work from. This design has a smaller shape and curves that allow us to use less material and stay under the 6 pound limit. It also isn't as well-known since the *God of War* games aren't ingrained in popular culture as much as Marvel is; additionally, the hammer only appears in a single, secret scene after the end of the game, so even many people familiar with the game won't have seen it before.

Figure 5: A screenshot of *Mjölnir* in *God of War* [12].

Design Process

After choosing a base design to work with, the next step was to decide what changes to make and draw up a design to model in SolidWorks 2019. We looked at the design as it appears in the game in Figure 4 and Figure 5 as well as other fan-made depictions.

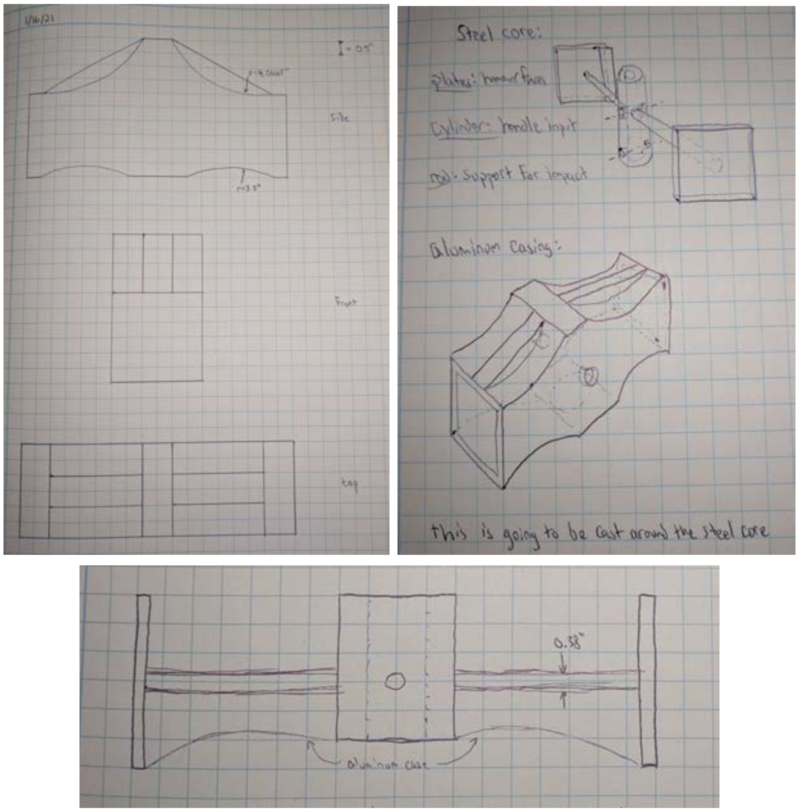


Figure 6: Sketches in David Matranga’s design journal.

As shown in the top right of Figure 6, the hammer was designed as a composite of steel and aluminum with a hollow interior. The steel core, shown in better detail in the bottom of Figure 6, has a cylindrical base for the handle with support beams attaching it to both faceplates, while the aluminum casing surrounds the core and makes the visual form of the hammer. This design was chosen to maximize size and strength while keeping the hammer within the six pound maximum weight limit given by the competition.

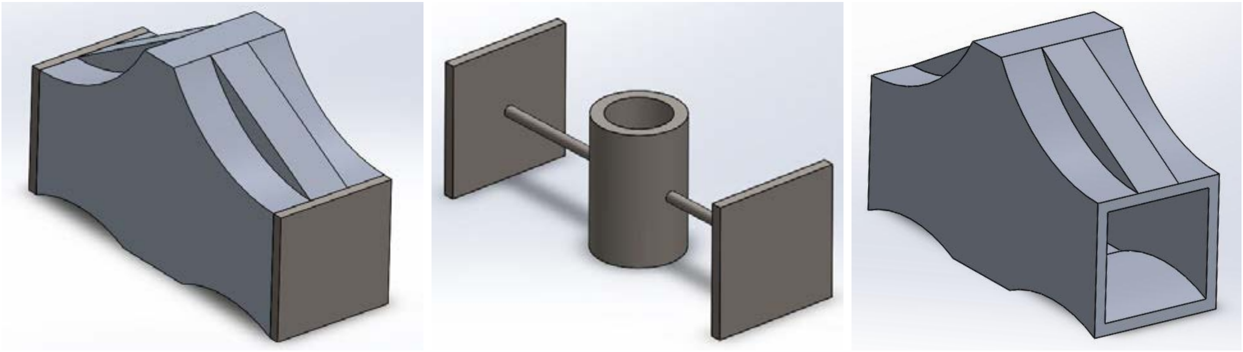


Figure 7: First draft of *Mjölnir* in SolidWorks.

For the final design, all sharp corners were rounded, the logos of The University of South Alabama and Howell Foundry were added to each side, a hole was added through the entirety of both the aluminum and steel pieces so the handle can be bolted into place, and a flair design was added to the bottom of the head.

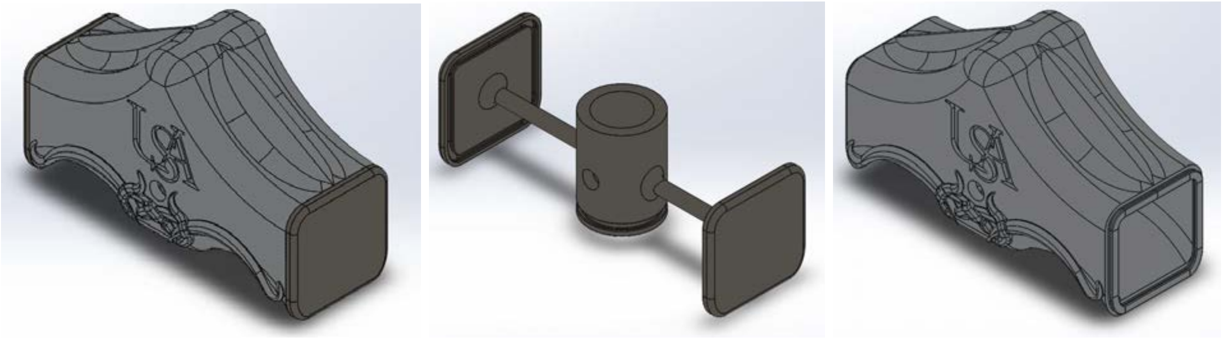


Figure 8: Final design of *Mjölnir* in SolidWorks.

To make the composite design work, small ridges were added into the steel wherever the steel and aluminum parts meet to hold them together, as can be seen in Figures 8 and in more detail in Figure 9. These holds continue along the entirety of the bottom circumference of the central cylinder and the inner edge of the steel plates. When the aluminum is poured, it fills these ridges and forms a solid attachment between the two pieces.

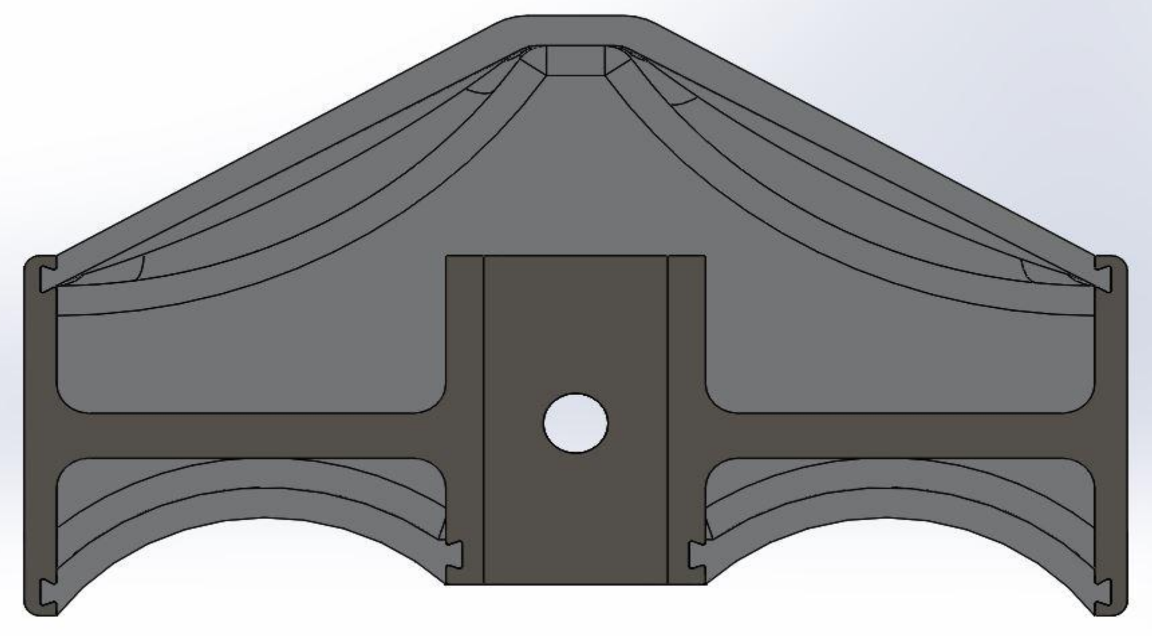


Figure 9: Center cross-section of the design in SolidWorks.

Technical drawings of the assembly and both components are shown below in Figures 10, 11, and 12. The design shown in these drawings don't have the bolt hole drilled through the middle because we decided it would be easier to cast the design without the hole and manually drill it afterwards. We made this decision to try and reduce the risk of defects in casting since we were only going to get two sets of molds and if they failed we would not have time to order more.

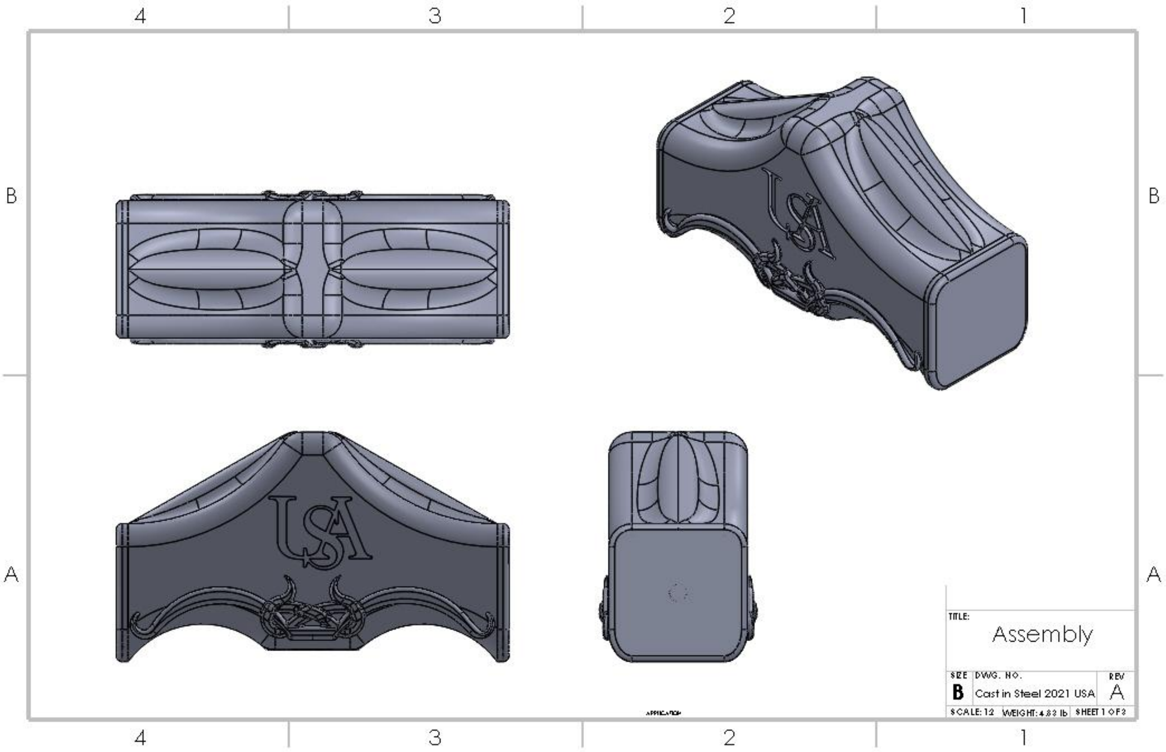


Figure 10: Assembly drawing of final hammer design.

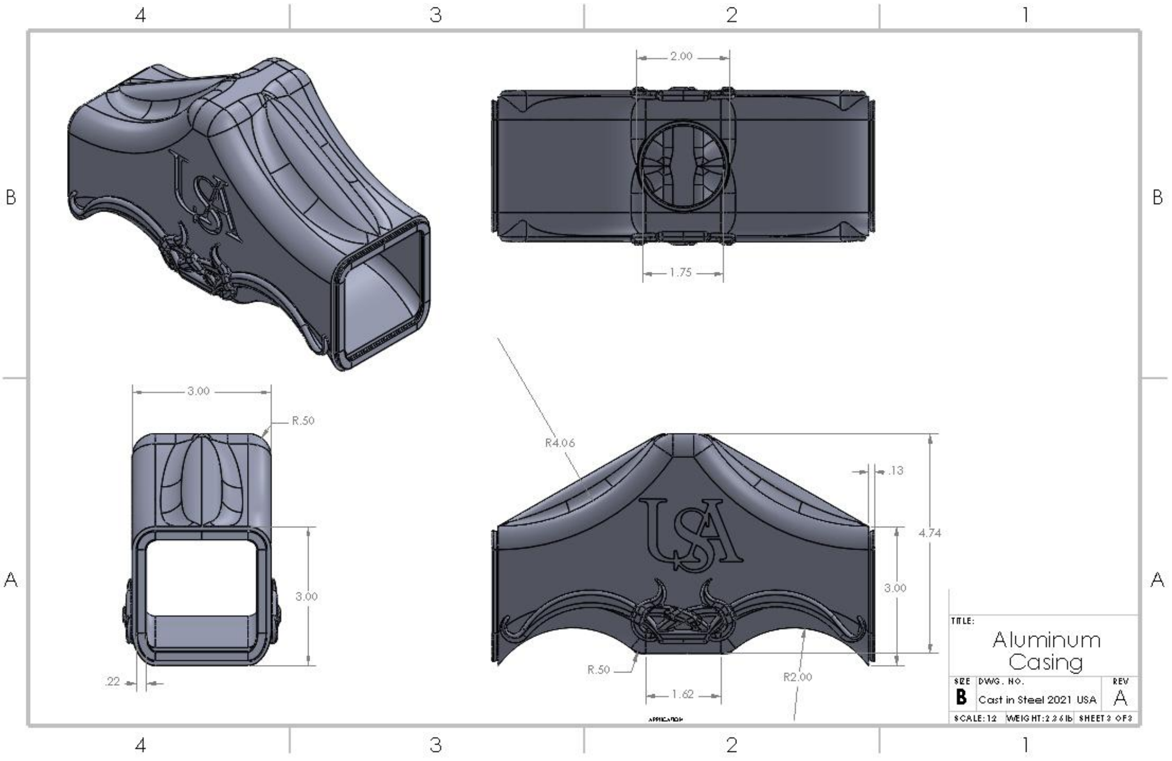


Figure 11: Aluminum casing drawing with dimensions.

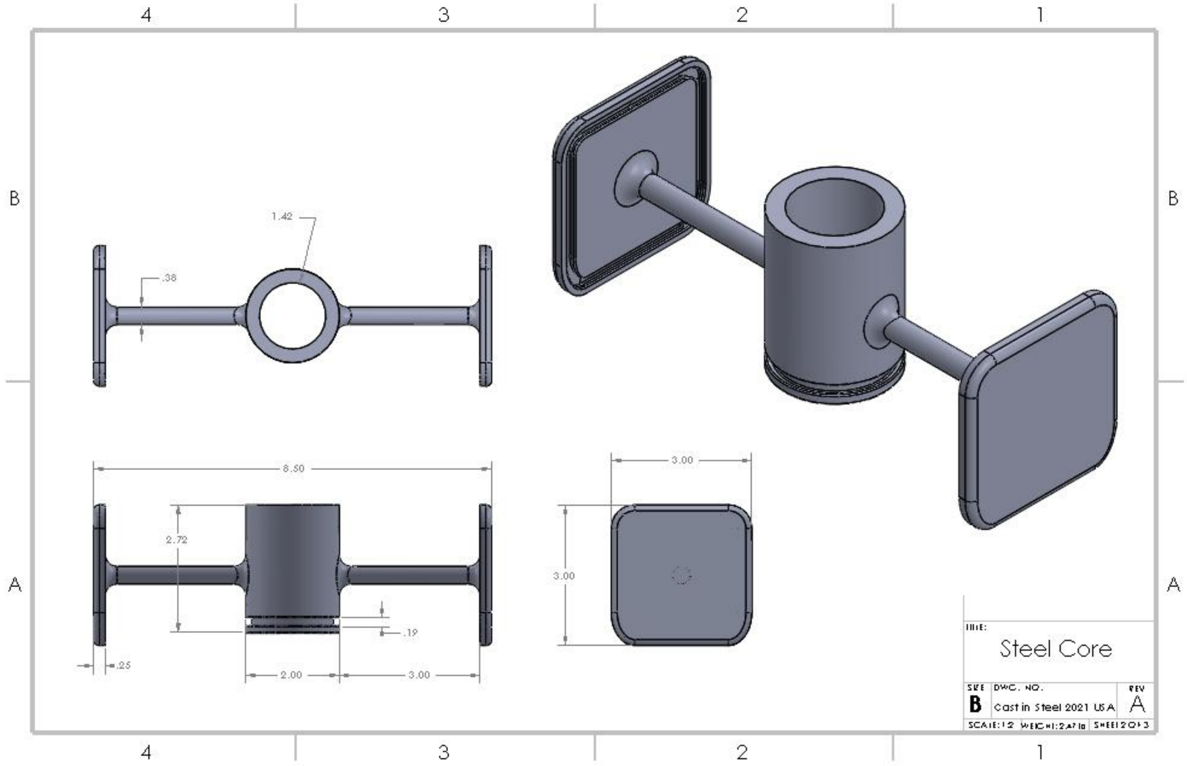


Figure 12: Steel core drawing with dimensions.

As seen in Figures 10, 11, and 12, the head of the hammer has a horizontal length of 8.5 in, a height of 4.74 in in the middle of the head, and a width of 3 in. The steel core is designed to take the brunt of the impact of any normal use of the hammer; its faces are in the shape of a 3 in square and are connected by a 0.38 in diameter rod to a vertical cylinder which serves as an interface for the handle. The ridges along the bottom of the cylinder and the edge of the inside of the faces allow the aluminum to hold onto the steel and have a thickness of 0.19 in and 0.22 in, respectively. The primary purpose of the aluminum casing is to serve as a lightweight method to fill out the form of the hammer, but it also provides extra support for the steel core.

This design is meant to allow all the impact forces and stresses between the handle and striking face to be concentrated in the stronger steel core and maximize the size to weight ratio. The steel core weighs 2.47 lb and the aluminum casing weighs 2.36 lb, giving the hammerhead a total weight of 4.83 lb.

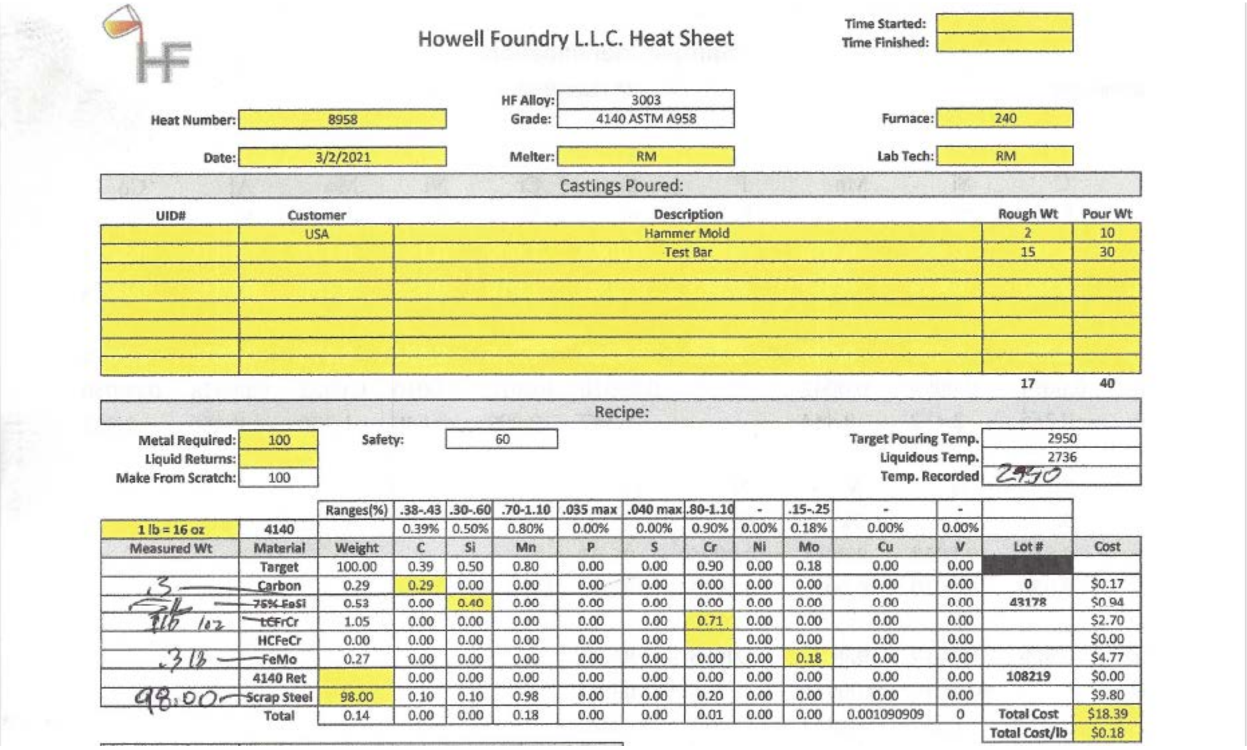
Material Selection

1. Steel Core: AISI 4130 Steel

When deciding on a specific material, the logical way to go about it was to look at the metals and types of wood used for hammers, and tools in general, that are already in the market. By doing so, we narrowed down the options for the head by looking at the maximum hardness that these materials would give us; we wanted maximum hardness in order to perform tests for a longer period of time without any signs of wear. Since hardness relates to abrasion, we looked for the best that we could get with the mindset that, the easier it is for it to wear, the lower its effective lifespan will be [13].

Our decision came down to two very good options that fit what we were looking for: tool steel and medium-carbon steel. It is important to note that tool steel is just another name for high-carbon steel. The more carbon there is in an alloy, the harder it becomes; however, tool steel requires investment casting, which our partner foundry does not do. We therefore used medium-carbon steel; more specifically, we wanted to use AISI 4340 as it has a little more carbon content than AISI 4130 and also it was a material that our partner industry knows how to work with well.

The AISI is the American Iron and Steel Institute and they have specific codes that regulate the amount of carbon and other components that are present in each metal. As mentioned above, our ideal material would have been 4340 for its higher carbon content but, in practice, making the 4340 from components at the foundry did not give us the desired values of carbon content which left us with AISI 4130 steel for the head of the hammer. The specific amounts of each element in our steel are shown below in a readout from an optical emission spectrometer machine used at Howell Foundry.



Howell Foundry L.L.C. Heat Sheet

Time Started:
Time Finished:

HF Alloy: 3003
Grade: 4140 ASTM A958
Heat Number: 8958
Furnace: 240
Date: 3/2/2021
Melter: RM
Lab Tech: RM

Castings Poured:

UID#	Customer	Description	Rough Wt	Pour Wt
	USA	Hammer Mold	2	10
		Test Bar	15	30
			17	40

Recipe:

Metal Required: 100
Liquid Returns:
Make From Scratch: 100
Safety: 60
Target Pouring Temp. 2950
Liquidous Temp. 2736
Temp. Recorded 2950

		Ranges(%)	.38-.43	.30-.60	.70-1.10	.035 max	.040 max	.80-1.10	-	.15-.25	-	-		
1 lb = 16 oz	4140		0.39%	0.50%	0.80%	0.00%	0.00%	0.90%	0.00%	0.18%	0.00%	0.00%		
Measured Wt	Material	Weight	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Lot #	Cost
	Target	100.00	0.39	0.50	0.80	0.00	0.00	0.90	0.00	0.18	0.00	0.00		
.3	Carbon	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	$0.17
.5lb	75% FeSi	0.53	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43178	$0.94
1lb 1oz	LCFrCr	1.05	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00		$2.70
	HCFeCr	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00		$0.00
.3lb	FeMo	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00		$4.77
	4140 Ret		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	108219	$0.00
98.00	Scrap Steel	98.00	0.10	0.10	0.98	0.00	0.00	0.20	0.00	0.00	0.00	0.00		$9.80
	Total	0.14	0.00	0.00	0.18	0.00	0.00	0.01	0.00	0.00	0.001090909	0	Total Cost	$18.39
													Total Cost/lb	$0.18

Figure 13: Optical Emission Spectrometer readout from Howell Foundry.

2. **Aluminum Casing: 1000 Series Aluminum**

The aluminum used for the casing of the hammer was similar to 1000 series aluminum and it was used for its lightness instead of for its mechanical properties. 1000 series aluminum is pure aluminum with little added alloying elements and it is a good material to use if you are using it for looks only as it has excellent corrosion resistance, making the part look brand new for a long period of time.

3. **Wooden Handle: Hickory**

The material selection for the handle of the hammer was very similar to what we did for the head: we researched the kind of wood that is most often used for tools that have a wooden handle such as axes, hammers, shovels, etc. We learned that there are several types of wood that are used for handles, some for shorter tools, like knives and chisels, and some for longer tools such as shovels and axes. We decided to choose a type of wood that would be cheap and easy to obtain and we decided on either hickory, oak, or pine. These options proved to be very strong and, although they don't differ in huge amounts, the best choice is hickory wood because it has an average elastic modulus greater than oak and pine and it also performs better than the other two in compression tests. The table below shows the results from the testings mentioned [14].

Table I. Material Properties for different wood types.

Type of Wood	Hickory	Oak	Pine
Average Elastic Modulus	1.7 GPa	1.25 GPa	1.4 GPa
Maximum Crushing Strength	4820 PSI	4360 PSI	4280 PSI
Highest Elastic Modulus Reported	1.98 GPa	1.49 GPa	1.89 GPa

Force Analysis

After modeling our design, we imported our Solidworks design into Ansys to analyze how it would be affected by an impact and find any weak points. We decided to use an impact force of 200 lbs directly in the center of one face as a baseline, assuming a point placed 2 in down the handle to be a fixed support. Ansys requires the material properties of each component in order to test it accurately; specifically the Poisson's ratio and Young's Modulus. For the steel core, we used AISI 4340 steel and for the aluminum casing we used 1000 series aluminum. The reason we modeled this simulation with 4340 steel was because the decision to switch from 4340 to 4140 was made later, on-site at the foundry. We used material properties found in books or other resources to do a preliminary test of the head [15, 16].

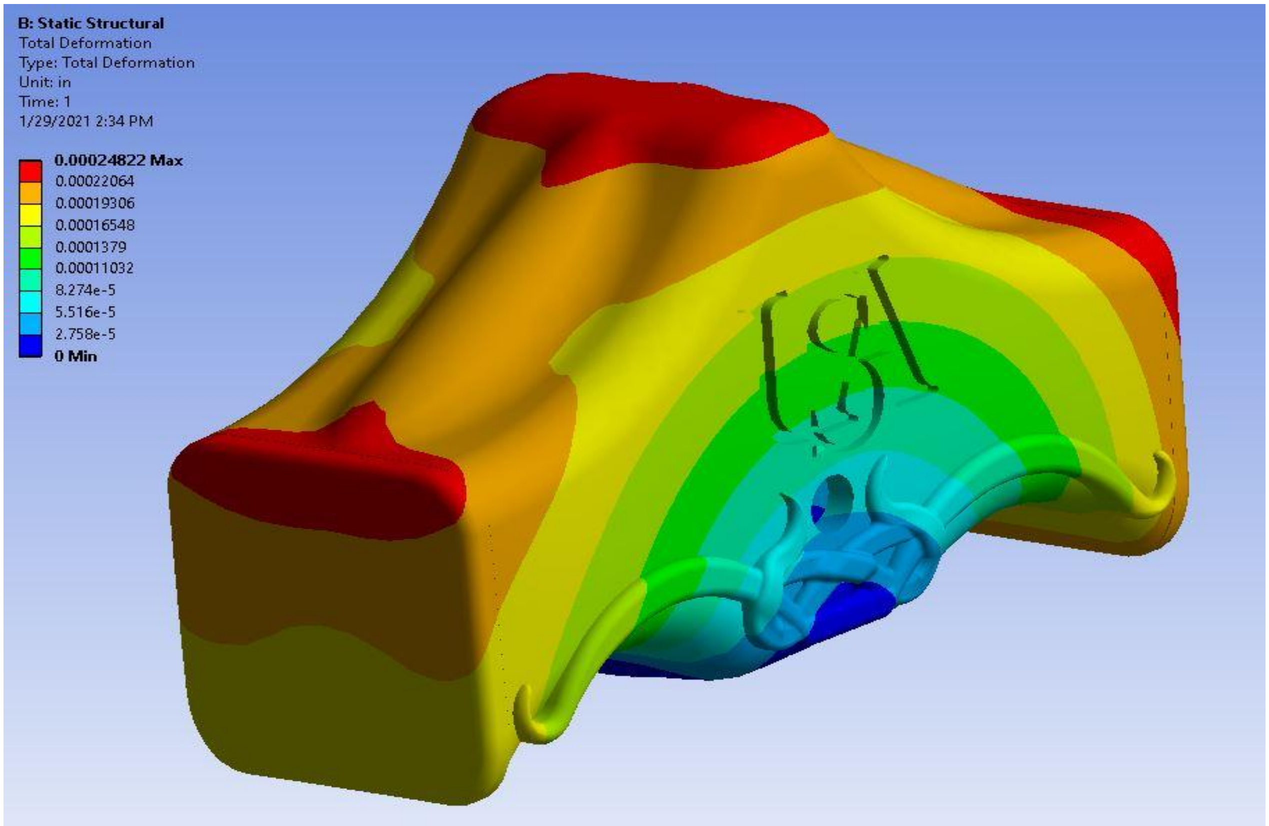


Figure 14: The deformation (inches) of the head of the hammer after a force of 200 lb was applied to one of the faces.

During the test simulations done on the head of the hammer, we were looking for maximum deformation as well as the maximum stress in critical sections of the hammer. The maximum stress was more important since it can be compared to the tensile and yield strength of the material to determine whether or not the material would fail or deform permanently. The tensile strength of 4340 steel is about 108 ksi [15], so we wanted to stay away from stress anywhere near that value. We used a force of 200 lb which would give us an idea of how much the head would change its shape after a reasonable hit. As shown in Figure 14, the deformation was at most around 0.00025 in. Next, we added a handle which was modeled as a cylinder of hickory wood and repeated the 200 lb simulation.

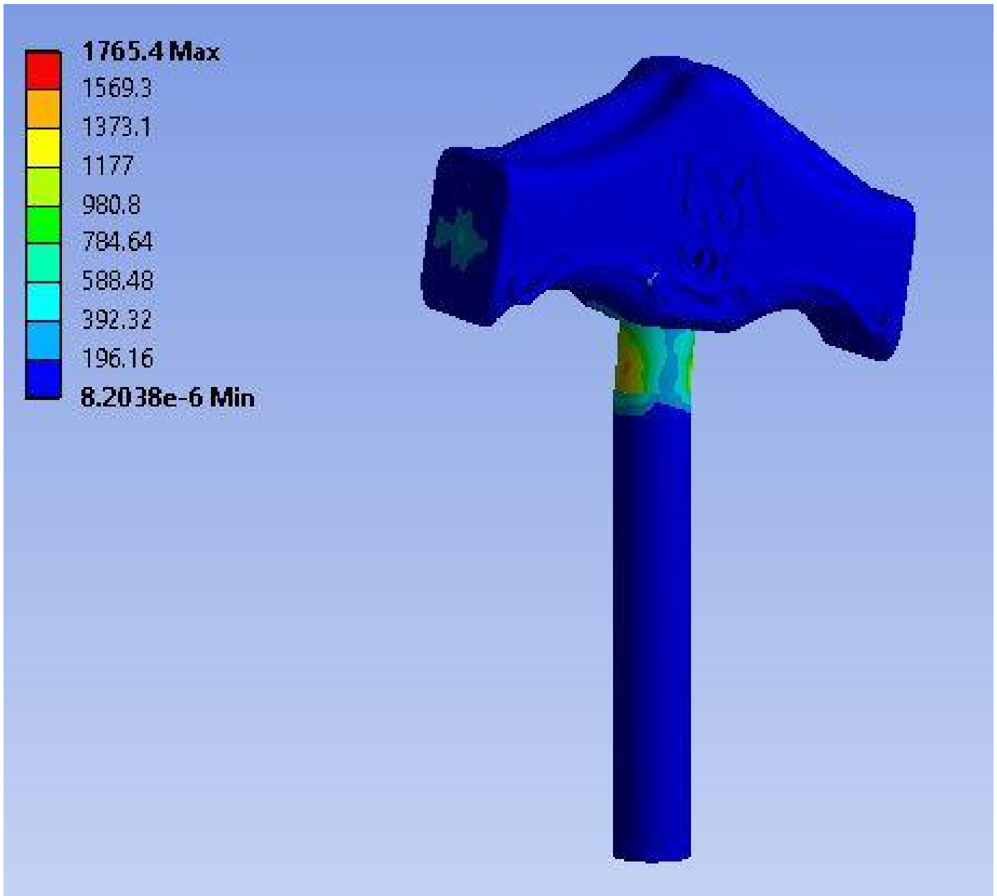


Figure 15: The von Mises stress (psi) for the whole hammer.

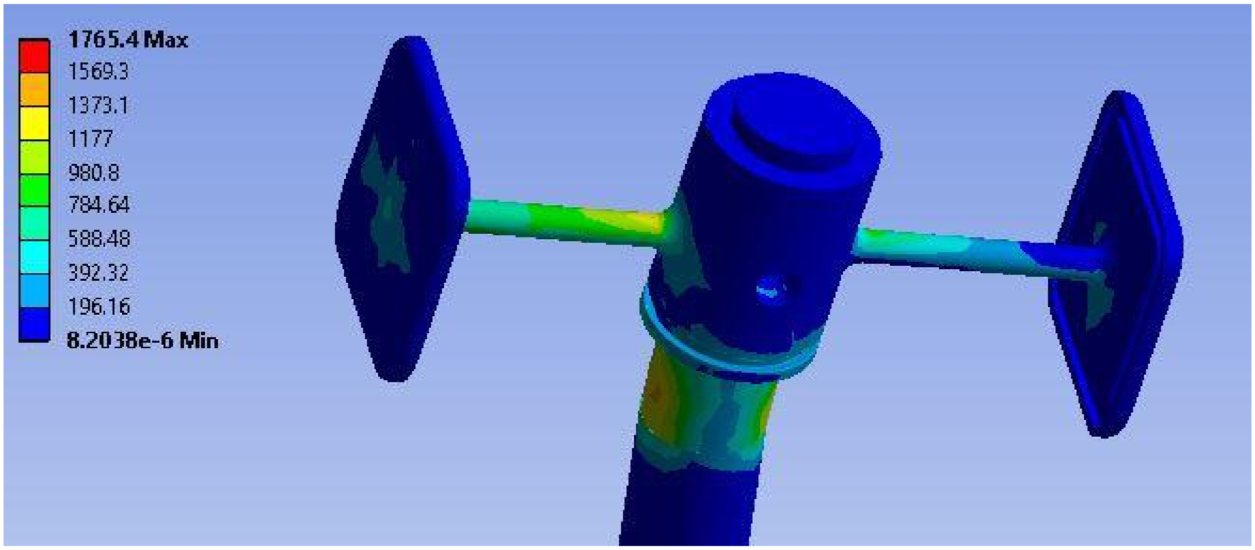


Figure 16: The same simulation as Figure 15 with the aluminum casing hidden.

As seen in Figures 15 and 16, the maximum stress experienced by the whole part with a 200 lb applied force was only 1,765 psi which is nowhere near the tensile strength of our steel. We repeated this simulation process multiple times using higher forces to find the upper limit for the hammer head and came to a stop at a force of 10,000 lb.

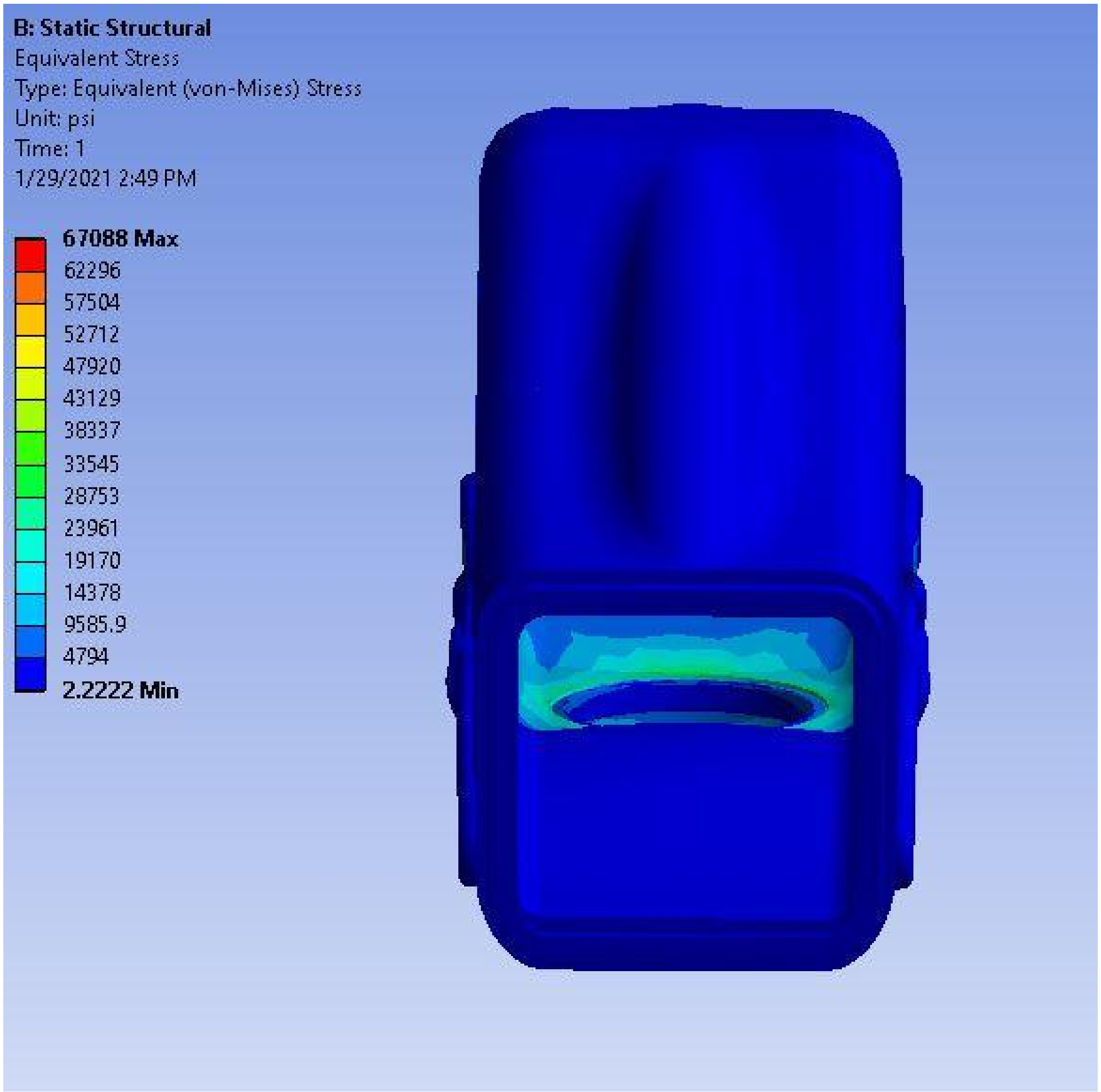


Figure 17: The von Mises stress for the hammerhead under a 10,000 lb force. (The steel core is hidden to look at the stress inside the aluminum casing).

From Figure 17, we can see that the maximum stress simulated in the entire hammerhead by the software was about 67,000 psi, which is only a little more than half of the tensile strength of the 4340 steel core, where that stress was located. The 1000 series aluminum, however, has a much lower tensile strength and hence is the reason why we were looking at the inside of the aluminum casing. The stress experienced by the aluminum has, according to our interpretation, a maximum amount of about 40,000 psi, the aluminum we used has a tensile strength of about 6,500 psi [16]. This means that the aluminum should break under a force well under 10,000 lb. Since the hammer is not likely to ever encounter a 10,000 lb force, but is much more likely to encounter a 200 lb force, we approved the design and sent it to Howell Foundry to start the casting process.

Casting Process

Our sponsor, Howell Foundry, specializes in sand molded castings which is a metal casting process that uses sand as a mold material. There are five main steps to this process: the first step is the creation of the pattern in the sand to create the mold. The second step is to incorporate a gating system that allows the molten metal to be poured into the mold. The third step is to remove the mold pattern from the sand when the sand takes the shape of the mold pattern. The fourth step is to fill the mold cavity with molten metal. The fifth step is to break away the sand mold once the metal has cooled down to remove the casting.

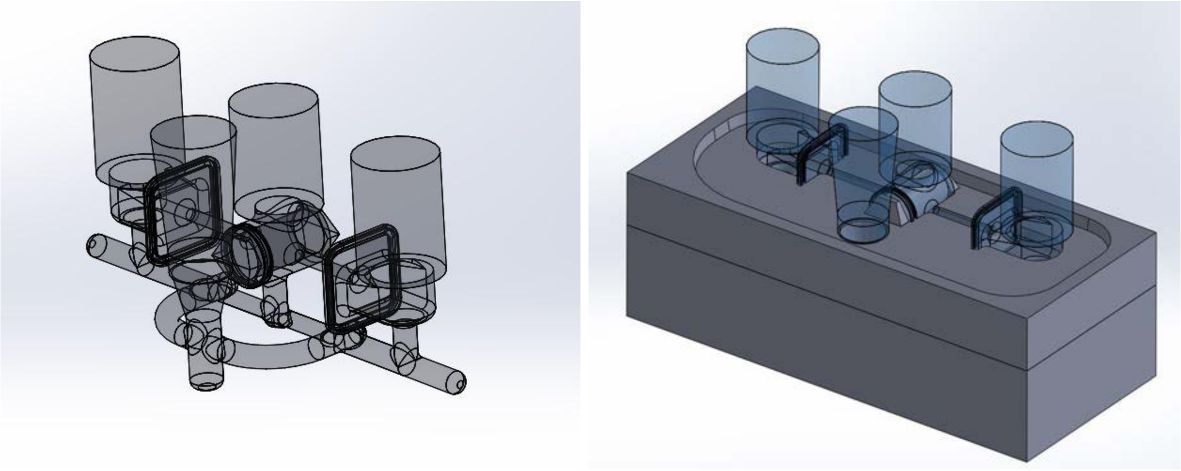


Figure 18: The riser/gating system for the steel core (left) and how it is set in the mold (right).

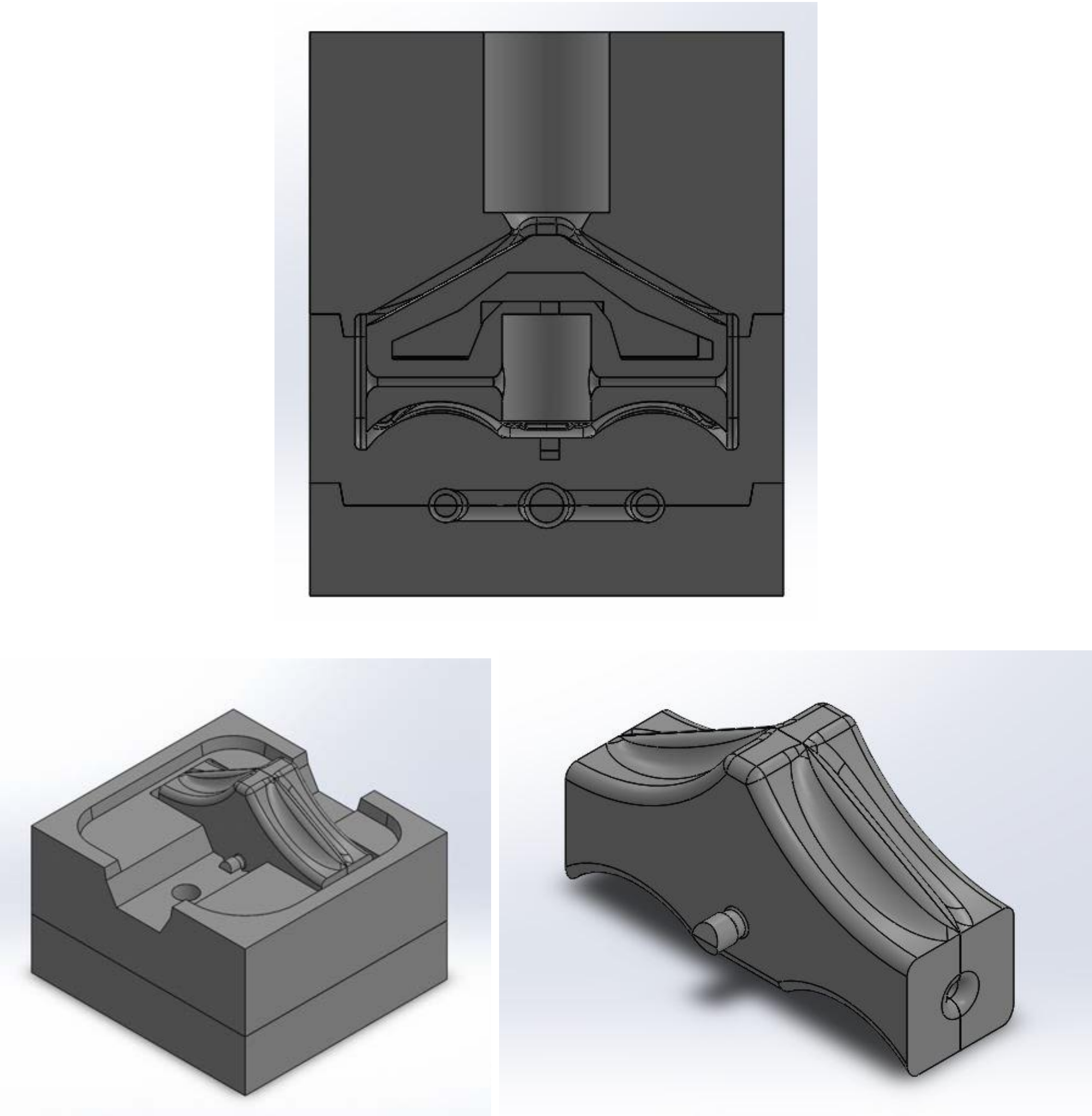


Figure 19: The aluminum casing mold's cross-section (top), middle with the top piece removed (bottom left), and hollow interior (bottom right).

For our design, we had the pattern 3D printed in order to have more precise dimensions for our design specifications as well as save time. Then our industry advisor, Joe Hutto from Howell Foundry, used our design to create the models shown in Figures 18 and 19 for the molds with the gating and riser systems. Once our molds were ready, we had to prepare them for the casting process by coating them with a paint designed to stop the molten metal from binding together with the sand in the mold. After the paint dried, we had to assemble the pieces of the mold and install the risers. Once assembled, we constructed an exterior block that would hold the mold together and protect against spillage from overflow or gaps in the mold. This exterior block was made up of sand and a bonding agent that, when mixed, created a solid block that surrounded the molds. Then we vacuumed all of the remaining sand that was inside mold and blew hot air into it to remove the moisture; this was done to minimize the risk of imperfections in the parts during casting. Now that our molds were prepped and ready, we moved them to a safe area for the pouring process.

Figure 20: The assembled aluminum casing mold (green block in the middle) and the exterior block (black block surrounding it).

In order to cast the composite design, two molds were required. The steel core was cast first as shown in Figure 21, and then after it solidified and was cut from the risers and gates with a blowtorch, it was heat treated for an hour at 1600°F and then for another hour at 1100°F. Once the treatments were done, it was placed into the second mold shown in Figures 19 and 20 where the aluminum casing would be poured around it. Both pours for our hammerhead went as planned, with the result of the final pour shown in Figure 22. Upon further inspection of the hammer, we noticed that there is a small gap in between the steel plates and the aluminum casing. Also, there was a small crack on the bottom of the hammer and the intricate design on the aluminum part had minor dents due to excess paint in the mold. It seemed that the aluminum poured into the ridges of the steel correctly but as it began to solidify and increase in density, it contracted which left a small gap in between the top of the steel faces and the aluminum casing as well as a crack in the bottom of the curve of one side of the aluminum casing. However, these minor imperfections do not affect the integrity of the hammer much. We also cast the backup molds in case our first cast was bad; however, the steel core that we cast the second time came out with too many imperfections and was not usable.

Figure 21: The steel core with the gates and risers after being removed from the mold.

Figure 22: The composite part with its gates and risers (left) and after they were removed (right).

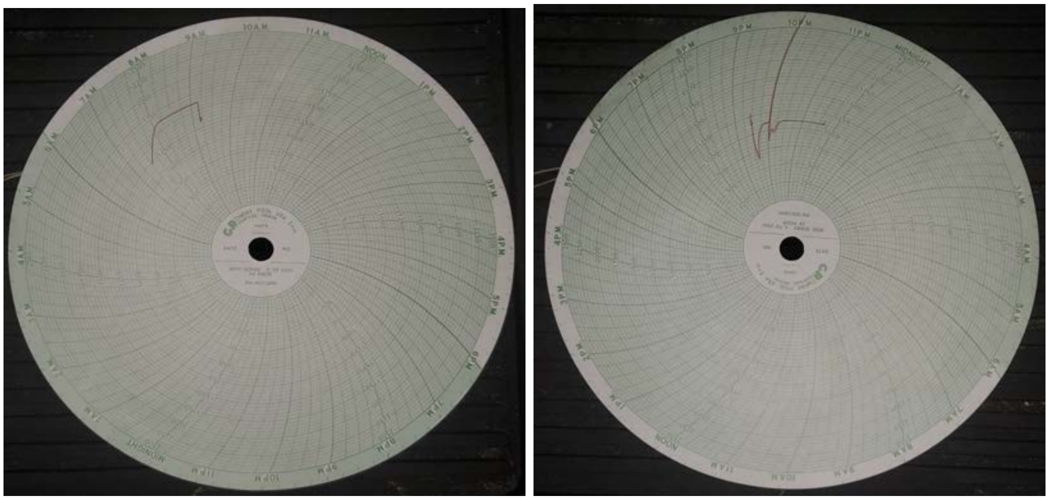


Figure 23: Logs of the two heat treatments done on the steel core before the aluminum casting.

Woodworking Process

Once the casting process of the head of the hammer was complete, we began to build the handle. After buying a 1”x 6”x 8’ piece of hickory board, we cut it into 20 in sections and glued two pieces on top of each other to get the correct dimensions for the width. While letting the wood glue dry, team member Willis Jones constructed a homemade lathe as shown in Figure 24, using a sheet of plywood, a 1”x 6” piece of pine wood, two bolts, two ball bearings, a drill, and a table saw.

Figure 24: A closeup of our homemade lathe.

After the glue dried, we cut the hickory wood into three sections, making each section 2”x 2”x 20”. We first tested the homemade lathe using a pine board of the same dimensions and it worked perfectly. Subsequently, we used the hickory wood and began to work on the handle. We designed the handle to have a larger diameter at the base of the handle, while the diameter of the handle close to the head of the hammer is smaller. This design helps the user maintain a strong grip while swinging the hammer. We used the drill to rotate the hickory wood while it was attached to the lathe and let the table saw turn the wood into a handle. After each pass of the table saw, we raised the saw blade and began again until the appropriate size was reached. We then used sandpaper to smooth the handle down. Once we determined the handle was complete, we used a miter saw to cut the handle down to 16 in and smoothed out the bottom of the handle. The handle was then sanded down using a sander to be able to fit 3 in inside of the head.

Detailing

After receiving the head of the hammer, there were a few pieces of leftover material from the risers and gate system still attached to the head shown in Figure 25. Using a dremel and several cutting wheels, we were able to grind those pieces down until the head resembled the original design. We then used a sanding attachment to smooth and polish the aluminum casting. Next, we painted the two logo engravings with black paint and the extruding symbols with gold paint. We also painted the dowel rod that covers the bolt gold to match the *God of War* design from Figure 4. Working on the handle, we used a router to curve the base so the handle would be rounded at the bottom. Once we stained the hickory wood with a dark stain, we wrapped the handle with a leather grip to create the pattern from our chosen design.

Figure 25: Head of hammer with leftover material.

Assembly

The assembly process consisted of jamming the thinner side of the handle into the bottom of the head and gently hitting the handle with another hammer, so there will not be any room for movement. Once the handle was 3 in inside the head, we drilled a hole into the handle where it matched up with the holes of the aluminum cast and put a bolt and nut inside to secure the handle. After we ensured the handle would not come out, we used a dowel rod to fill the gap left by the two holes in the cast. As shown in Figure 26, we cut the remainder of the dowel rod and sanded it down to make it flush with the rest of the head.

Figure 26: Assembled Thor's hammer.

Final Product

Once all the fine details were finished, we were left with Thor's hammer, pictured in Figure 27. The final product resembled our initial design from the *God of War* franchise.

Figure 27: Completed *Mjölnir*.

Following the assembly and detailing process, we were able to begin testing of our completed hammer. While being cautious as to not damage the hammer before the competition, we tested the performance of our Thor's hammer by smashing various items that would be considered normal use for any ordinary hammer. These items include bricks, glass, and fruits, among other things. The hammer's performance showed that we designed a fully functioning hammer capable of accomplishing the tasks a regular hammer would be able to perform.

Conclusions

Over the course of the Cast in Steel project, our team has overcome many challenges that tested our abilities. We faced a three week setback because the molds were delayed due to the winter storm that swept across the United States. Once the molds came in, we had to rush to get the project finished. Overall, we learned several valuable skills pertaining to the casting industry. The opportunities provided by competing in the Cast in Steel competition allowed us to gain valuable experience in the engineering field, which we will use on future projects.

Special Recognition

On behalf of The University of South Alabama Cast in Steel team, we would like to extend our appreciation to Joe Hutto and Howell Foundry. Without their expertise and equipment, we would not have been able to cast our Thor’s hammer. We would also like to show our appreciation toward the University of South Alabama’s Mechanical Engineering department, including our project advisor, Dr. Melike Dizbay-Onat, and our Capstone Design professor, Dr. Dhananjay Tambe, for giving us the opportunity to participate in the competition and giving us the knowledge and guidance to accomplish our objectives. Finally, we would like to express our gratitude towards Kimberley Schumacher and the Steel Founders’ Society of America for sponsoring the Cast in Steel competition, allowing college students to obtain experience in the casting industry.

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