Thor's Hammer

Submitted to

Kimberley Schumacher

By

Texas State University: Students

Max Casares

Matthew Candelas

Margaret Lee

Jordan Wood

American Foundry Group: Sponsor

Abel Ardis

Texas State University: Faculty Advisor

Dr. Luis Trueba

This paper will discuss the design and process used for the making of a steel hammer. This hammer was made by Texas State University students and our sponsor, American Foundry Group Inc. We will discuss our reasoning behind our design, the materials selected, and the modeling process used.

Table of Contents

Acknowledgments

We would like to express our most sincere appreciation to Abel Ardis of American Foundry Group Inc. for his support, guidance, knowledge, and patience in aiding us with our project. His willingness to give his time and advice so generously has been very much appreciated and beneficial in manufacturing our hammer.

Body

We designed our hammer to resemble the hammer seen in the video game, God of War. We also took inspiration after researching the famous Norse god, Thor. These stories that are still told today are always changing but the fact that always stays the same, is the connection between the God of Thunder and his hammer of lighting, Mjöllnir. Our adaptation of this hammer consists of a triangular lattice structure on both outer walls, with a similar lattice structure inside to provide support, while allowing us to make our hammer larger yet still within the criteria. We added ornate engravings along the surface to decorate this mighty weapon, as well as adding each of our names onto each corner of the hammer in Elder Futhark. This is the language that was believed to be spoken by the Vikings and is most closely related to the legend of Thor.

The style and shape of our hammer was designed to reflect our inspirations, as well as provide a strong, large hammer that was under 6 lbs. During the age of the Vikings, the people would etch the symbol of Thor's hammer into their possessions to honor their god and be protected. This symbol can be seen embroidered onto clothing, worn as jewelry, even etched into their coffins. We wanted to stay true to the legend and make a hammer that was both mighty, yet honorable.

During the concept selection phase of our design process, our team created two designs. After careful consideration of the casting method and limitations, applications of the hammer, and Magma results, we were able to take the best of both designs and combine them into our final hammer design. We were able to keep the size close to the legends of the Mjöllnir by making our structure hollow and removing material on the outer walls. Our hammer has a unique webbing on the sides that was designed to provide strength, support, and easy casting. The outer walls are also designed to allow for a larger lighter hammer, but still strong. Triangles are one of the strongest shapes because of their resistance to deform under pressure. Both the outer walls and the inner support structure mimic a triangular lattice shape (Figure 1).

We selected a 10-b modified with vanadium alloy steel for our hammer. This alloy was selected because of the high hardness, toughness, and impact resistance it has. This alloy has a hardness roughly between 277-332 BHN, a high tensile strength and elongation, which is important for a hammer, so it does not deform when force is applied. The chemical composition of this alloy was modified with vanadium to enhance these needed characteristics (Figure 2). These features were critical for us to produce a hammer that would be able to withstand impacts and blunt force. This material was also heat treatable, which was a characteristic we desired for our hammer.

Our sponsor Able Ardis works at American Foundry Group which is where the casting process was done. We chose to use investment casting as our process because of the unique shape and attention to detail. We strongly believed that investment casting was going to be our best option and most efficient in terms of yielding a completely defectless casting.

Our group decided to create the hammer head in Solidworks. Once we finished the design, we then sent the step files to Abel so that he could run it through MagmaSoft to conduct a solidification analysis. In this stage of the competition, we were able to see a simulation of how the hammer would act during the solidification process. With this software, we were able to see areas of shrinkage, the mesh analysis, temperatures at all the nodes when it was poured and how different gating areas would the casting solidify with minimal risk areas. By using Magma software, we were able to design a gating system that would limit the most porosity, shrinkage, and cold shuts in the casting (Figure 3) .

Once our team was satisfied with the design and solidification analysis, we proceeded with printing a wax model that could be used for investment casting (Figure 3). Our team was able to print a wax hammer using castable wax resin on Formlabs Form 2 at our university. Due to time constraints and the delicate nature of the casting, our sponsor also reached out to a 3rd party to 3D print a few more for security. On the pattern, we included the engravings so that they would be included on the casting and we would not have to machine them in after. The triangle lattice on the outer walls were also cast into the hammer so we would not have to machine them. Doing so would have added a wasted process in our overall manufacturing process. Moving forward, it was time to build the dip shell that would surround the wax (Figure 5). We had the 3D wax hammer connected to the tree in eight places. We chose to do it this way because it allowed for the best flow during the pouring process and to ensure that the intricate outer walls and inner structure would fill completely. Once the wax hammer was connected to the tree, the investment coating was added. Our next step was to melt the wax out of the shell, pour the casting, and lastly heat treat and sharpen. Our sponsor poured the hammer head out of our selected material, and heat treated the head. The heat treatment consisted of normalizing the head at 1700 F for two hours, air cooled at 1650 F for one hour, then water quenched. Finally, we tempered the head at 1200F for three hours and ended with a water quench (Figure 6). This heat treatment was used to ensure the proper hardness and strength was achieved in the hammer.

Our last step was to attach the handle to the hammer. We modeled the handle in Solidworks to fit our head, and then used a router to machine the handle out of oak wood. Oak was chosen because it was a hardwood, yet still light weight. Once the handle was attached, we stained the wood and wrapped it with leather to give it a more comfortable grip and robust appearance. We added a small lightning bolt to our handle to honor the God of Thunder. Our final hammer weighs 5.6 lbs. with a total length of 13.5 inches (Figure 7).

Conclusion

We believe that our hammer will hold up in both strength and destructiveness. The design will provide strength and size yet keeping it light weight. The alloy and heat treatment will provide added strength and toughness. Due to the design and processes used we believe that our hammer will exceed our project requirements.

Photos

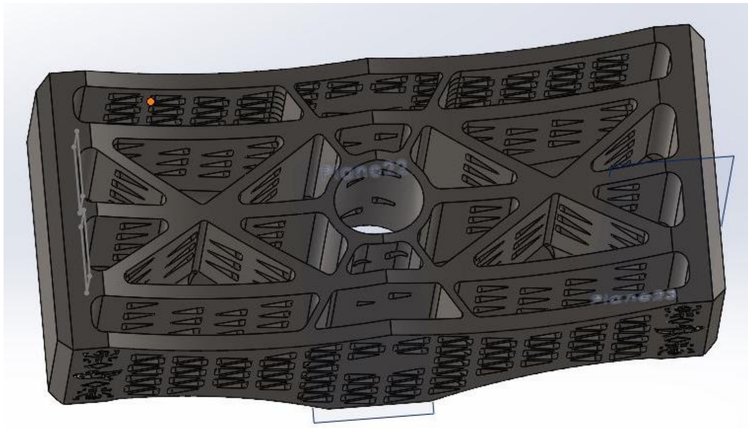

Figure 1
Bottom view of our hammer showing the lattice framework on the inside.

Burn Number	1G302F
Heat Number	1G302
DATE	4/14/2021
TIME	10:07:10
Operator	MVM
Division	AI
Material	10B MOD

Import

FE_	95.50448	N	.00594
C	.19501	NB	.00775
MN	.86755	AS	.00357
SI	.47478	B	.00043
CR	.67655	BI	.00039
NI	1.70111	CA	.00053
MO	.37671	CE	
P	.01246	LA	.00007
S	.00643	TA	.00957
V	.05947	TE	
FE		ZR	.00343
CU	.03257	NI_	
W	.01893	CO_	
CO	.00388	CD	
SN	.01027	AG	
SB		CU_	
ZN	.00406	CEQ	.677726333
AL	.01069	PREN	2.014733
PB	.00104	Ferrite	-.295115175
TI	.01135	CbplusTa	.01732
MG	.00097	CuplusNi	1.73368

Figure 2
The chemical composition of our alloy.

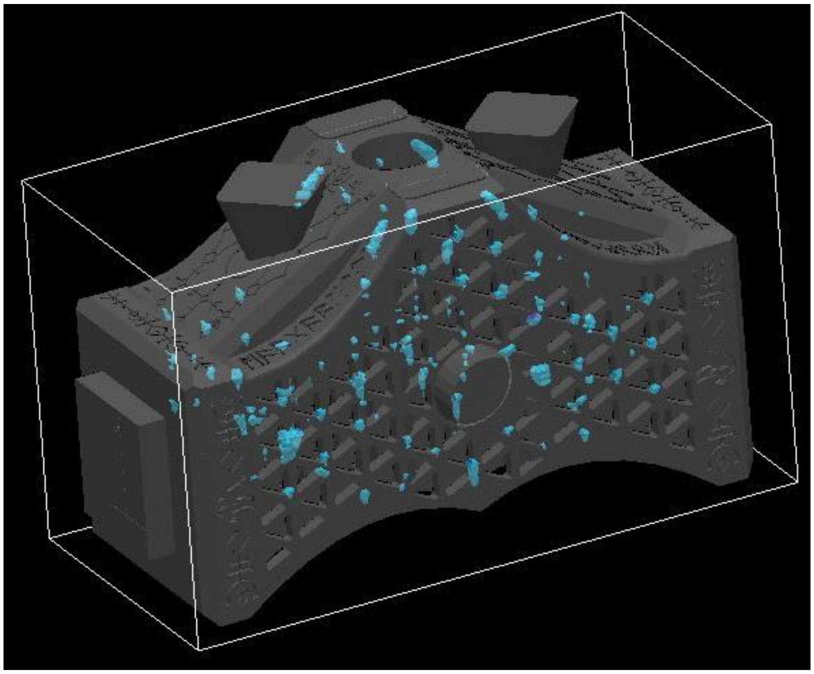

Figure 3
Results from MagmaSoft showing potential porosity.

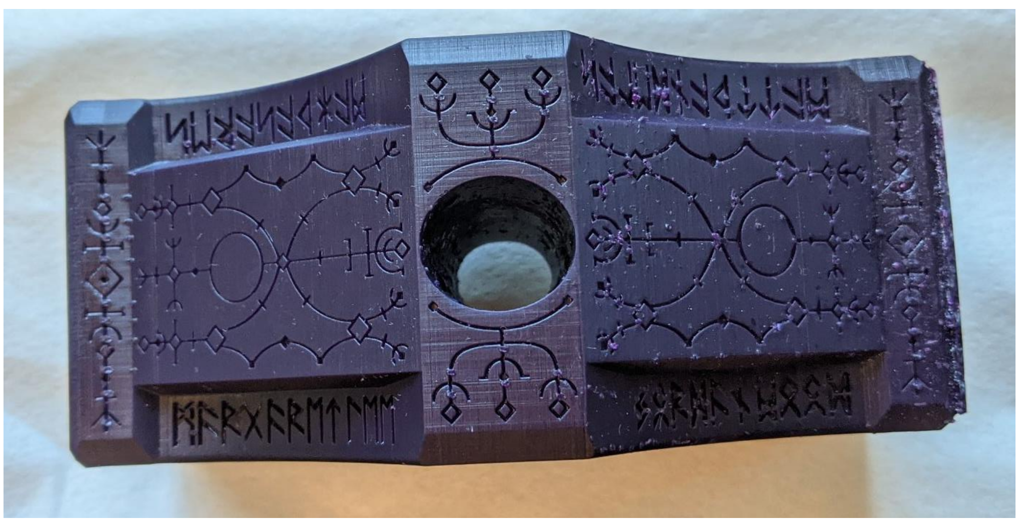

Figure 4
This is our 3D wax printed hammer.

Figure 5
Our hammer coasted in the ceramic slurry and ready for casting.

American Foundry Group Outside Heat Treatment Requisition						
	AFG PO Number		Date	4/15/2021		
Approved Supplier Name	PHT		Pc. Cnt	1 BUCKET	WEIGHT	32 LBS
AFG Procedure Number			BHN Range	277-332		
Heat Treat Time & Temperature	NORMALIZE 1700 F FOR 2 HR MIN PLUS 1HR/1" OVER 1" THICKNESS - AIR COOL					
	1650 F FOR 1 HR MIN PLUS 1HR/1" OVER 1" THICKNESS - WATER QUENCH					
	TEMPER 1200 F FOR 3 HRS WATER QUENCH					
Quench Cycle Yes	X	No	Air	Fan	Water X	Oil
Required Heat Treat Chart	Yes X	No	Required Hardness Yes	X	No	
Additional Comments	NO SCALE, PROCESS STEP CERTIFICATION REQUIRED					

Customer	PO Number	Pattern Number	Material Type	Pcs.	ID Number	S/N
TEXAS STATE		THOR HAMMER	10 B MOD	4		
TEST BAR						
1G302						

Figure 6
The heat treatment process for our hammer.

Figure 7
The final result of our hammer.