Thor's Hammer SFSA Competition

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Design Phase

The constraints of the competition include designing a one-handed hammer that weighs no more than 6lbs and needs to be shorter than 20 in, and the hammer had to be cast out of steel. During the initial design phase, these constraints were initially ignored as the creative design was brainstormed, Utilizing various depictions of Thor's hammer from the internet the premier design was sketched on a whiteboard and was used as a guide for when the team built the hammer using CAD software.

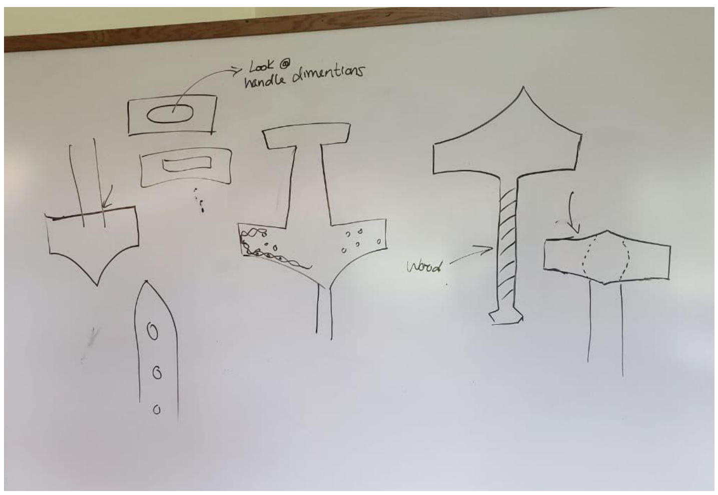

Figure 1: Design Brainstorming

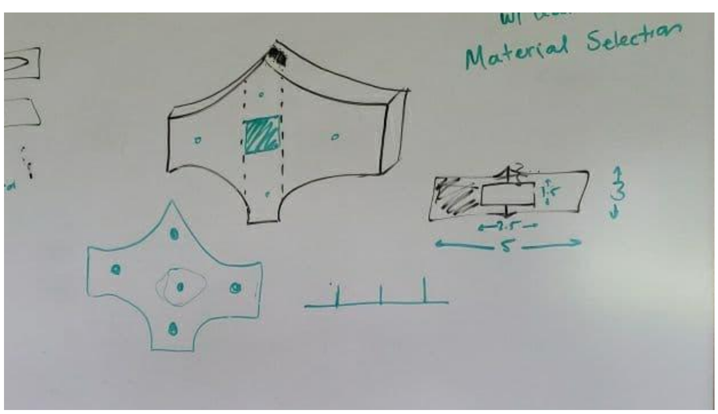

Figure 2: Primary Design with Dimensions

Figure 2 represents the primary design that was chosen with rough dimensions of what the team wanted the hammer to look like. Knowing that the hammer was going to be cased out of steel the team recognized that the whole hammer could not be solid. However, the team also wanted to use the side faces of the hammer to include artistic depictions of Thor and include images relating to some of Thor's stories. A compromise was concluded by developing a hollow hammer with internal supports and using a faceplate design that could be cast separately and then attached to hide the internals. Using AutoDesk Inventor, a CAD model was constructed showing the internal design of the hammer.

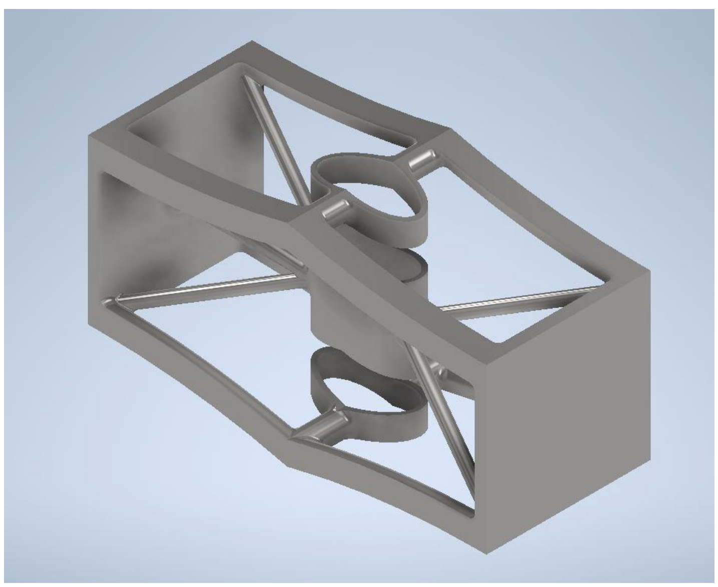

Figure 3; Internal Design of Hammer

Upon completion of the CAD file, the team quickly fell in love with the unique design and opted to continue the project, not including a faceplate. Verifying the strength of the hammer an impact analysis was performed using ANSYS. This test consisted of simulating what would happen to the hammer if the head impacted a solid flat object that would not yield. The results showed that the hammer would not experience any breakage and would not experience drastic deformation. The team was satisfied with the results and opted to 3D print a prototype to better visualize what a final hammer may look like in person.

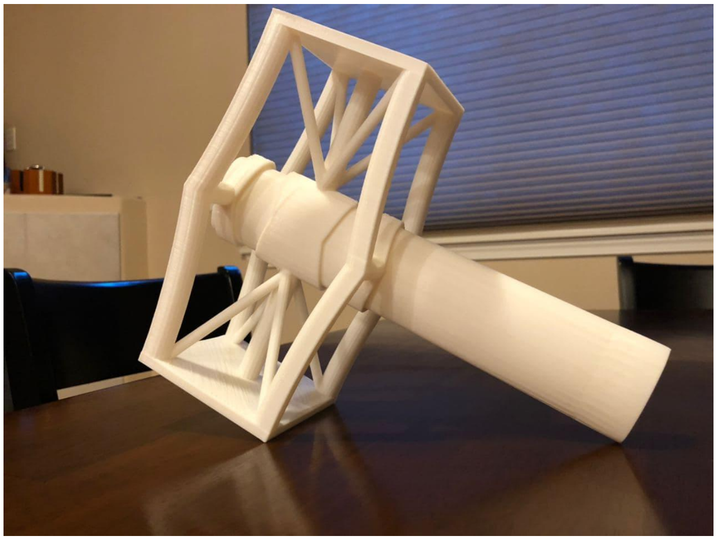

Figure 4: 3D Printed Prototype

With the model in hand, the team decided that the internal design should be redesigned to look more aesthetically pleasing and so that the supports were connected to separate parts of the hammer and not converge on a single point with the fear that it could create a stress concentration and a point of failure. In addition to this, the team wanted to now focus on creating a hammerhead weighing roughly 5lbs and leaving 1lb for the weight of a wooden handle. Building off of the initial design a second model was made in CAD and also 3D printed.

Figure 5: Second Iteration

The second iteration included arches into the internal design to better distribute the energy from an impact and a member spanning from the center of the face to the handle to better support the face. The original design had 3 center rings for the handle to fit in, but to cut back on weight a single center hole was chosen. To further save on weight, the hammer face was transformed from a common rectangle to a rectangle with concave edges.

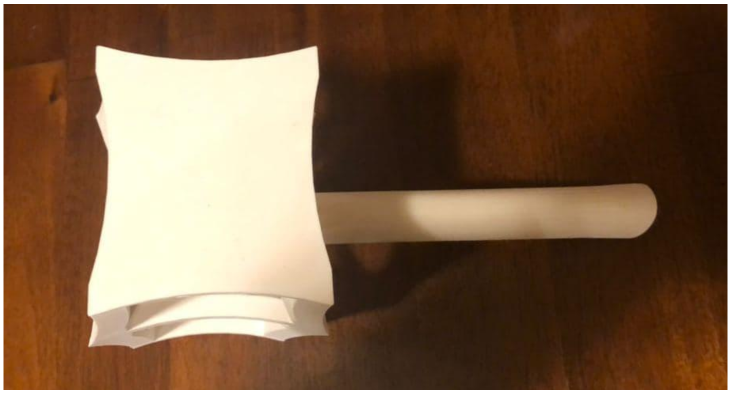

Figure 6: Hammer Face with Concave Edges

Not being completely satisfied with the final hammer, the team went back to the CAD model to further iterate upon the design. The team enjoyed the curves that were introduced into the second design and decided to create another hammer that featured the arch design more prominently. Below is the 3D printed prototype of that design.

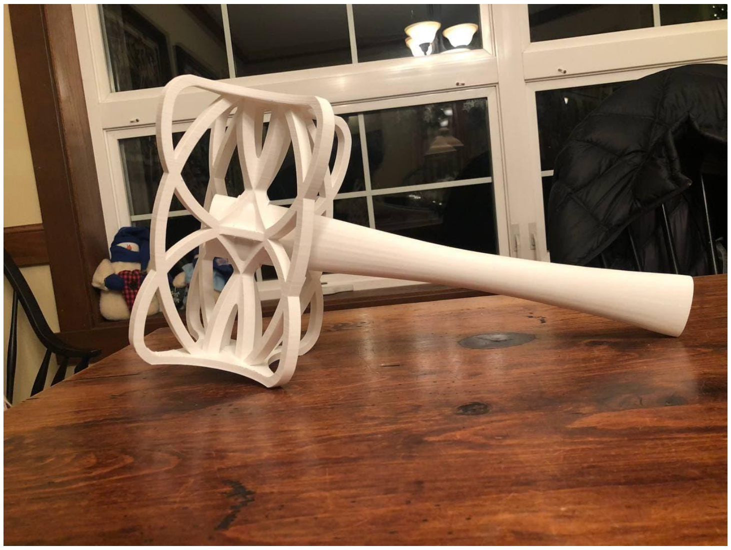

Figure 7: Arched Hammer Design

Seeing the final design in person blew the team away. This design was extremely unique and beautiful at the same time. This design quickly became the favorite, leading to it being chosen as the final prototype.

Casting Phase

Moving forward from the final prototype the partnered foundry, Tacoma Industries was contacted to determine the feasibility of casting such a hammer. The foundry responded detailing the possibility of investment casting the hammer given that a few alterations were made to the CAD model to make it more easily cast. The recommendations made to the team included rounding all edges, adding a dome to the back of the hammer to help with the flow of the molten metal, and including a riser so the metal can be poured into. Seeing the 3D printed prototype, Tacoma Industries also recommended providing them with a 3D printed model so they can cast the hammer using a form of lost wax casting.

Figure 8: 3D Printed Cast Model

The initial prototype was cast out of PLA, but to ensure accuracy for the final mold the material, PolyCast was selected. PolyCast is a 3D printer filament that was specifically designed to be used for lost wax casting. PolyCast also has the ability to be smoothed using IPA vapors to reduce the prominence of layer lines in the final model.

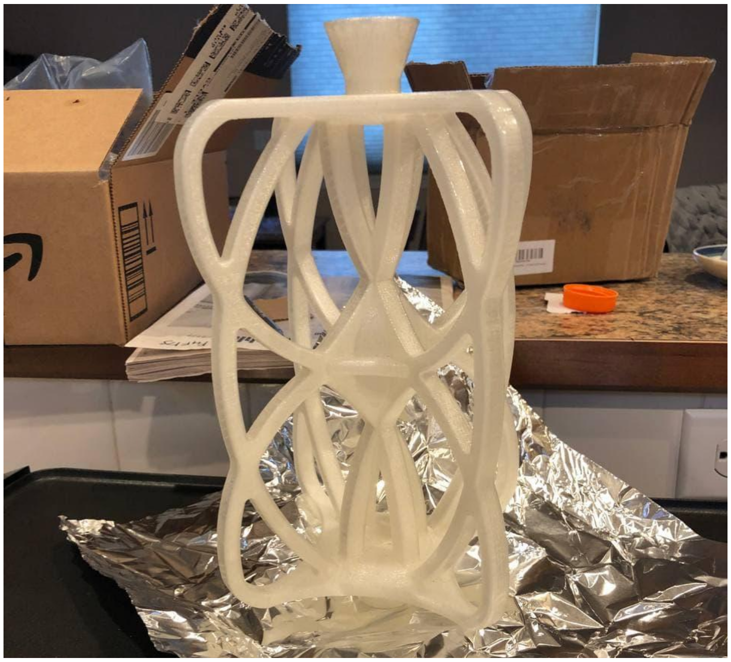

Figure 9: Smoothed Model

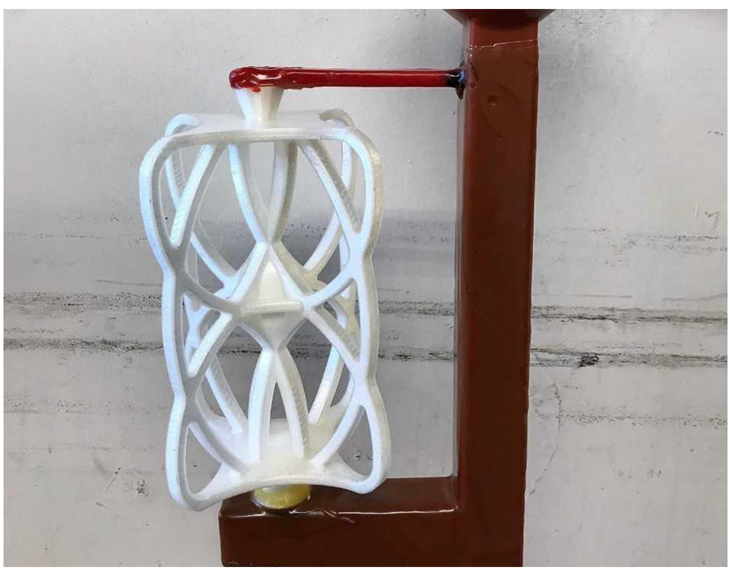

Figure 10: Casting Tree (Spokane Industries)

Figure 11: Shell Coating (Spokane Industries)

Per Spokane Industries, after the model was casted it then went through the following heat treatment process. "The heat treat cycle was: 3 hour ramp to 1900 F. Hold for 30 minutes (austenitize). Fan cool. 1 hour ramp to 900 F. Hold for 1 hour (temper). Air cool" (Spokane Industries). After the treatment the final model was then tested to determine the hardness reading. Spokane Industries reported a hardness reading of 48-50 Rockwell C.

Figure 12: Casted Hammer Head (Spokane Industries)

The initial hammerhead pours from Spokane Industries came back almost in perfect shape. The only defect that regularly occurred was a hole occurring on one side of the back of the hammer face.

Figure 13: Defect on the Hammer

Spokane Industries reported that this defect is occurring because of their processes and not because of the model. They would need further test models to better tune their process so that the final will come out defect-free. Spokane Industries was able to remedy this defect by attaching additional risers and tuning the temperature of the metal. Unfortunately, given time constraints a final defect-free model was not able to be prepared in time for the competition.

Construction Phase

The construction phase consisted of finishing the casted hammer, carving the handle, and then fitting the handle to the hammer. The process used for finishing the included grinding minor imperfections and eliminating the black oxidation layer, followed by wet sanding of the hammer using an increasing amount of grit size to get a polished finish. For grinding, a combination of an angle grinder and a Dremel bit was used to grind the top layer of the hammer. The grinder was used on the face, while the Dremel was used on the inside and hard-to-reach areas. Following up the grinding process wet sanding was used to clean up the scuffs left behind from grinding. Starting with a coarse grit and working to a finer grit size the following sizes were used to sand 60-120-400-800-1500.

The team then moved on to selecting which type of wood to use for the handle. Research showed that hardwoods are favored to be used as handles as they are less likely to break and bend. Using that knowledge the team selected to use Bubinga wood, as it is a hardwood and looks gorgeous. To shape the handle a slab of Bubinga was into a rectangle with the rough dimensions of the size of the handle. From there the general handle shape was drawn by hand and then a band saw was used to cut the wood. From there the team had the handle shape down but in the form of a rectangle. To get the oval shape the wood was sanded using a combination of a belt sander and hand sanding.

To fit the handle to the hammer a cut needed to be made to the top of the handle to make room for a wedge to fit in. A wedge was then cut and formed out of poplar. Poplar was selected because it is a softwood, and when wedged into the handle cut it will expand the handle so that there is a tight fit between the handle and the head. After the wedge was hammered in, another metal wedge was hammered in as well to prevent the softwood wedge from falling out. This completed the final hammer.

Testing Phase

To test the hammer the team needed to come up with some way to test the hammer so that way if it would be used by Thor the hammer would be successful. With the lack of Frost Trolls in the area, the team decided to smash fruit instead. The team theorized that if the hammer can smash a coconut, then it should be sufficient to smash mythical creatures as well. In addition to this, the team also believed that Thor may not be the most tempered individual and may be easily agitated with the littlest things. That is why home appliances were brought in. If the team was able to successfully demolish a microwave then Thor would be content to take his frustration out the next time he tried to warm his soup and the bowl ended up hotter than the soup. Finally, the team wanted to push the limits of the hammer and see how well it would fare against a rock. Unfortunately, the hammer met its demise here. After the collision, the hammer was still attached to the handle and still was able to smash fruit but some cracks formed in the hammer along the cross-section of certain arches. These cracks were concerning but did not mean that the test was a fail. The hammer used was the only hammer that was currently available at the time, and that was one of the first casted hammers that contained inherent defects in it. All the cracks from the rock impact occurred near the casting defects. This means that the reason for the failure is inconclusive and will require further testing in the future.

Roadblocks

The team faced some major roadblocks during this project. The main issue we ran into was the first casting partner. In October the team contacted a local investment casting foundry to be able to cast the hammer. They were very enthusiastic at first and said that they really wanted to do it. But as time went on they stopped responding to any emails sent by the team and it resulted in a termination of the partnership. This left the team scrambling to be able to find a new casting partner with only a few months left to go. In January, Kimberly from the SFSA managed to find a new casting partner in WearTek and Spokane Industries. This was a perfect partnership as the team was able to work closely with these partners to try and complete the castings in just a month and a half. While some castings were able to be produced, the final hammer design or a perfect casting was not produced due to the time constraint and issues with the initial castings. This resulted in the submitted hammer being a hammer with a defect on one face and lacking designs that were added to later castings. Despite these roadblocks Team Thud along with our partners WearTek and Spokane Industries were still able to produce a beautiful and strong hammer for the competition.

"Fortunately, I am mighty!"

~Thor