MEC 3320

Casting Lab Report

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Abstract

The purpose of this project was to design, simulate, and then pour an aluminum cast of three chosen parts. Initially, each of the three parts were simulated through Solid Cast individually to identify any potential issues with casting them. After the initial iterations of the three models were determined, they were combined into a single mold and a gating system was added. Three iterations of this final design were chosen and to be reported based on the lessons learned from each one. The main changes within each design were placement and thickness of risers as well as some adjustments to the parts themselves. The final iteration of this design showed a relatively successful simulation with a strong density distribution for each part, and a correct distribution of solidification times for two of the parts. In the final iteration, these two parts solidify before their respective runners, followed lastly by the riser, which is the correct order for solidification. However, one design wasn't able to fully solidify before the runner due to its geometry, but in each iteration the shrinkage effects were reduced significantly. The final design weighs 1.35 pounds with a percent yield of 31.3% and takes 2.72 minutes to fully solidify. This optimized iteration is the design that will be used to cast the three parts.

Summary of Proposed Design

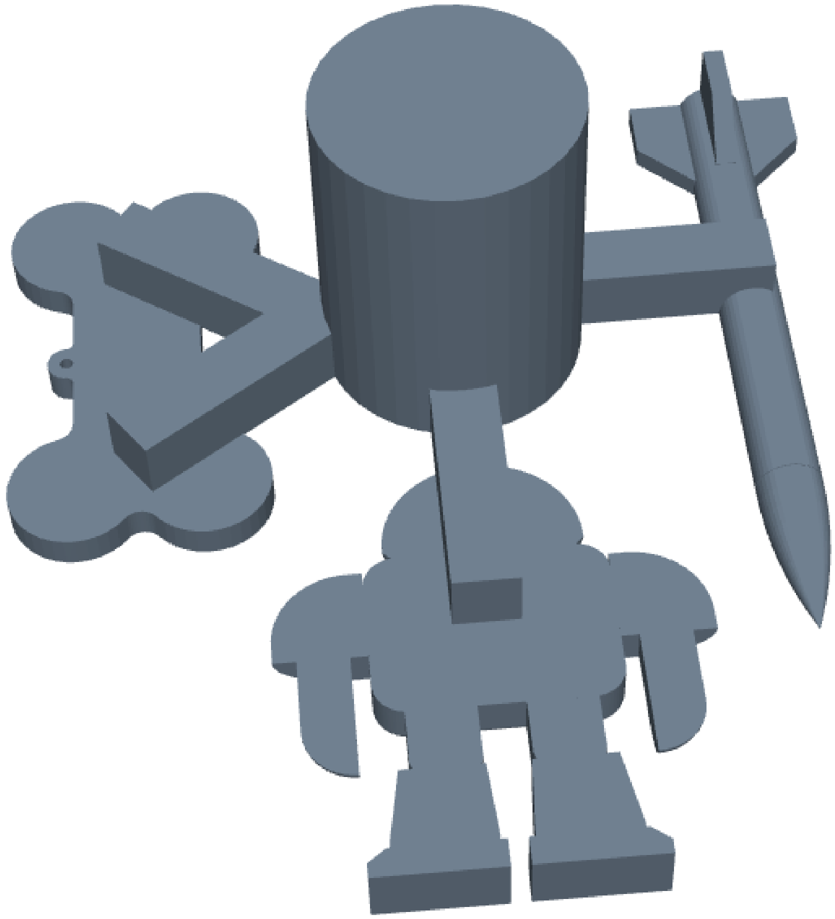

Figure 1: Overall layout of parts and gating system.

The final design created to cast the three chosen parts can be seen above in Figure 1. Not pictured in Figure 1 are the sprue, pouring cup, and vent holes that will be used in the true casting process. The sprue will be directly on top of the riser connected to the pouring cup, and 1-2 vent holes will be added to each part. Each runner shown in the final design is 0.5 x 0.5 x 2 inches, and the riser has a radius of 1 inch and a height of 2.5 inches. The dog tag and the robot are both flat on one side, so they will be 3D printed as one part. The rocket is slightly more complex and will be split in half on the parting line in order to properly make the mold.

The parts that will be created are plastic 3D printed molds that form a cavity as seen in green sand. Two main pros in green sand casting include a low investment cost which is ideal as learned in class. Additionally, it allows for common metals and a wide range of part sizes, which is ideal for this lab, as three different parts are going to be cast. The downsides include fragility and relatively low filling speeds, which will need to be kept in mind while performing the cast.

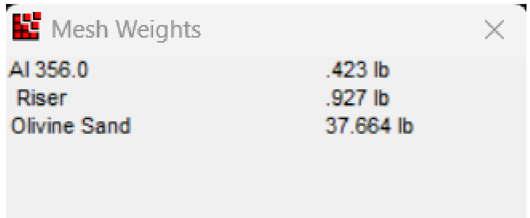

Figure 2: Overall layout of parts and gating system.

One important consideration when casting is the final weight as well as the percent yield. As shown in Figure 2, the total weight of the aluminum casting is 1.35 lbs. Using the equation for the percent yield, the value for this model is found to be 31.3%.

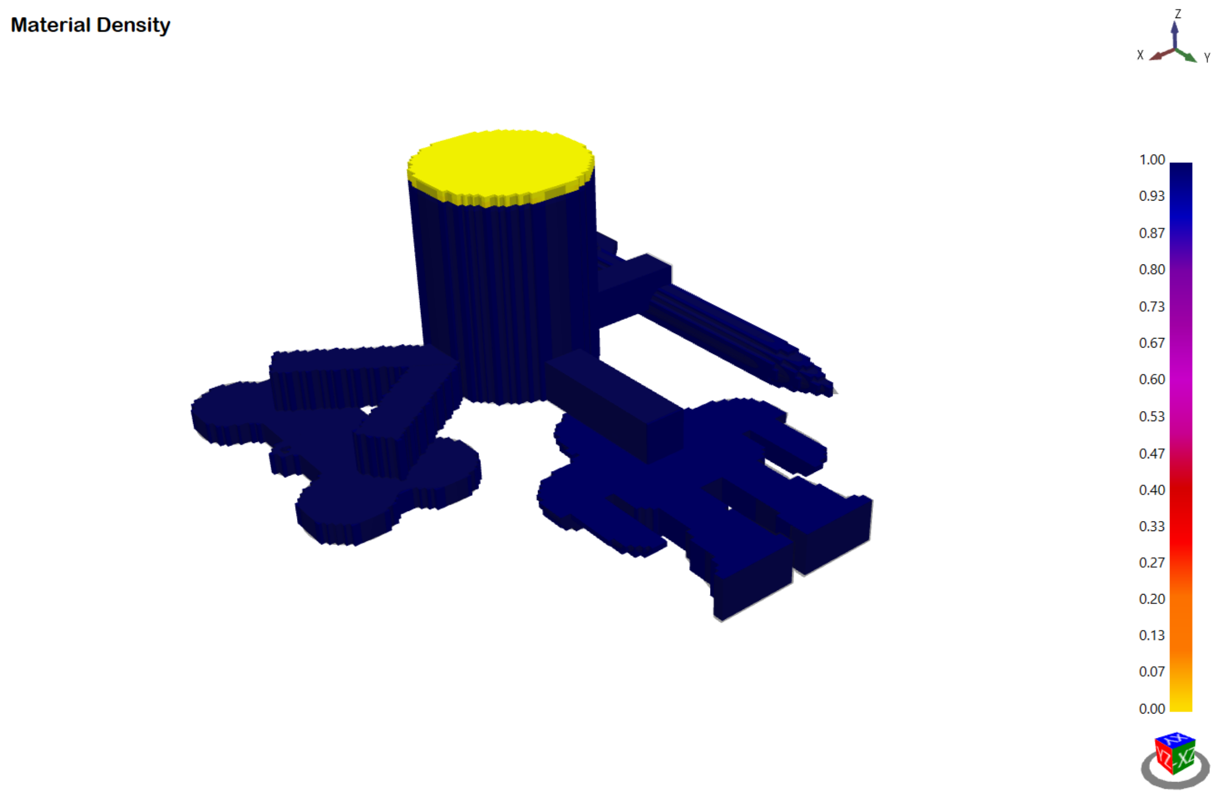

Figure 3: Final design material density plot.

An important model to use for casting simulations is the material density after solidification. This plot for the final design can be seen above in Figure 3. A material density plot shows how uniformly a casting will solidify, and where there may be concerns for shrinkage or incomplete feeding. As seen in Figure 3, the only area with low density in the final design is the top of the riser which is not an important part of this casting, making this a valid and ideal plot.

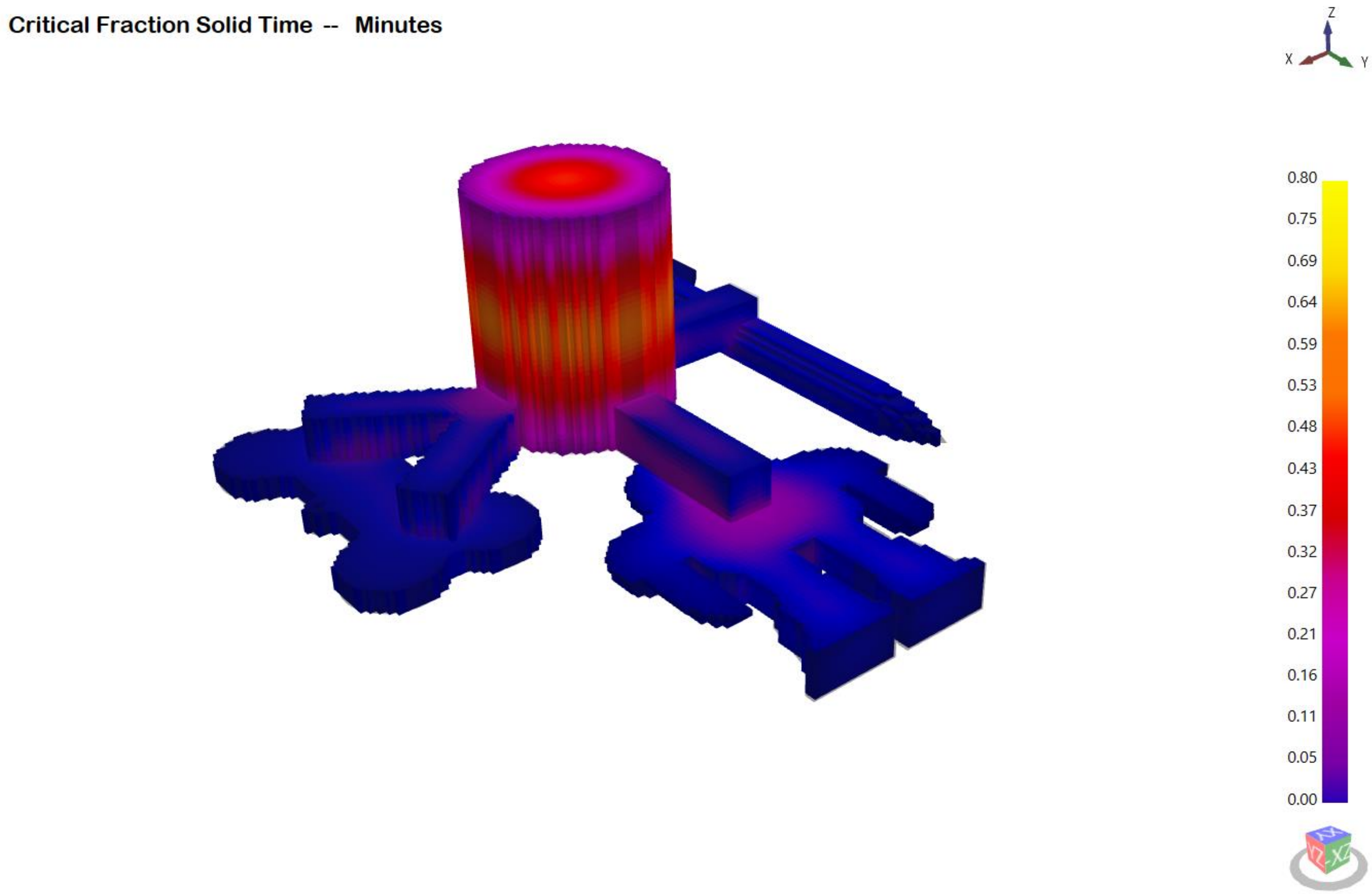

Figure 4: Final design critical fraction solidification time plot.

The other very important model to plot for a casting is the critical fraction solidification time. This plot shows the length of time it takes all areas of the parts and gating system to fully solidify. Analyzing this final plot as well as a movie of the solidification over time is extremely important, as this shows which parts, runners, or risers will solidify first. In a perfectly ideal scenario, the parts will solidify completely, followed by the runners to each part, and then finally the riser. When visualizing the step by step of this iteration's solidification, this is true for the rocket and the dog tag, however the robot and its riser solidify almost simultaneously. Figure 4 shows the slightly concerning location in the center of the robot, where the riser and robot will likely solidify at the same time. This issue was investigated and could not be solved without changing the robot even further to make it unrecognizable, or adding unrealistic risers, so the risk of incomplete feeding or shrinkage will be taken.

Background Material

Solid cast Individual Parts

<u>Dog Tag</u>

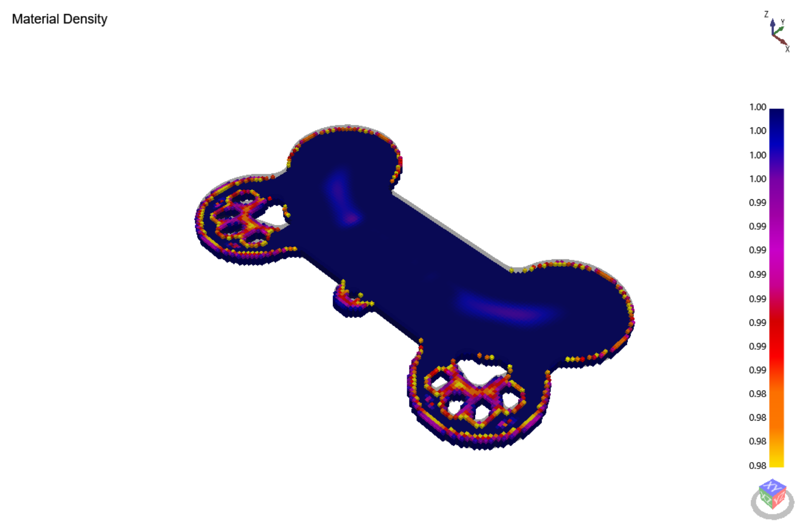

Figure 5: Material density of dog tag.

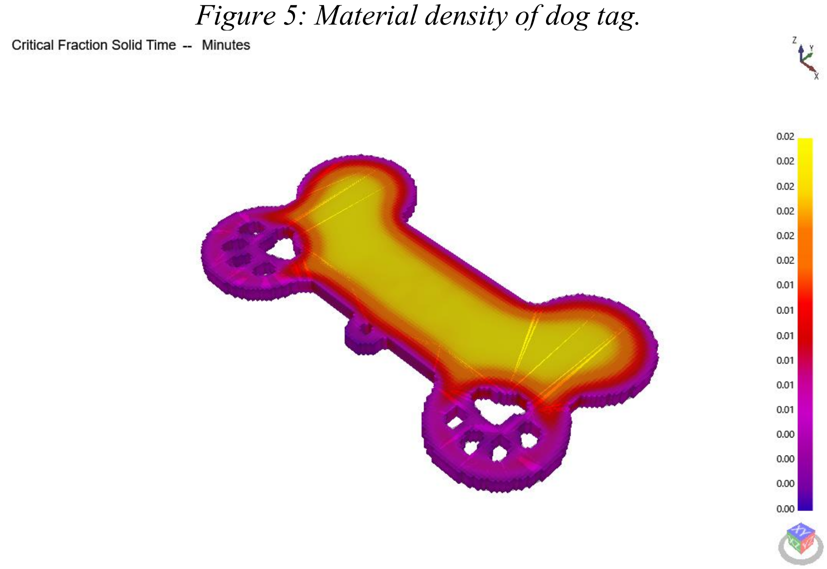

Figure 6: Critical fraction solidification time of dog tag.

The dog tag first iteration is seen above with the material density and overall critical fraction time graphs. There were a couple of potential issues that were addressed in a second iteration. In the area around the paws, the density is a bit low which will lead to some porosity potential. This area was fixed in the second iteration to make the paws only have a partial indentation to help allow for more aluminum to fill in the gaps around the paw as it solidifies and shrinks. In changing this part of the paws, the entire part was also made thicker. Additionally, there are two slightly lighter parts that were identified in the center which should be used for the runners.

Rocket

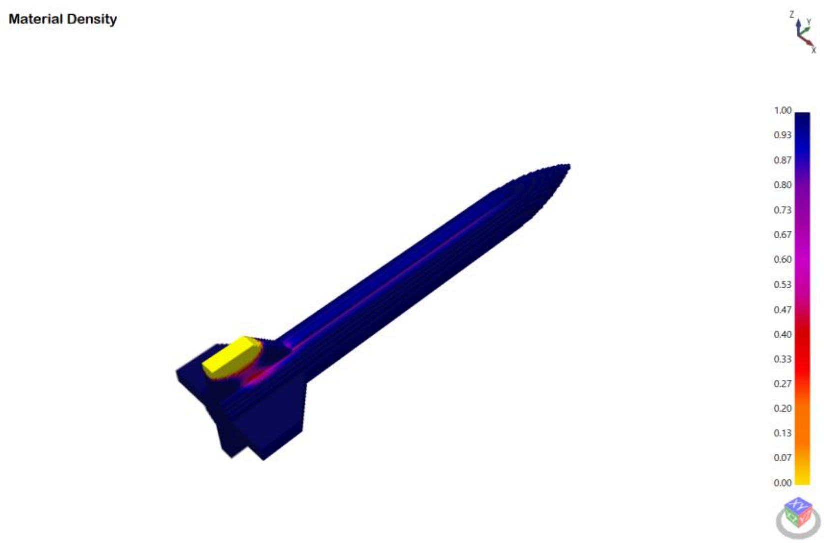

Figure 7: Material density of rocket.

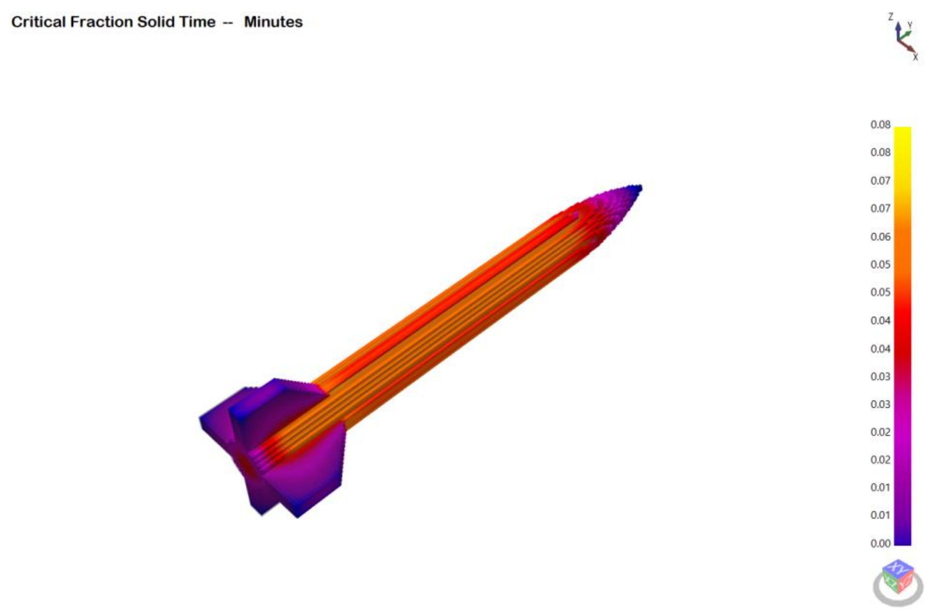

Figure 8: Critical fraction solidification time of rocket.

The rocket's final iteration is seen above. Since the first iteration, the fins have been made much thicker, and the shape has changed to allow it to be pulled out of the mold correctly. In Figure 3, the material density on the top fin is shown to be very low and problematic when the rocket is modeled by itself. While this would be true in a normal solidification of the rocket by itself, it will be shown later that when a riser is added, it will solve this density issue. The addition of the riser will ensure the highest point in the cast is above that fin, which allows for pressure to fill the entire fin. The increase in pressure will theoretically solve the low-density issue in the top fin. When the riser is added it will create the necessary pressure for this part to be successful.

Robot

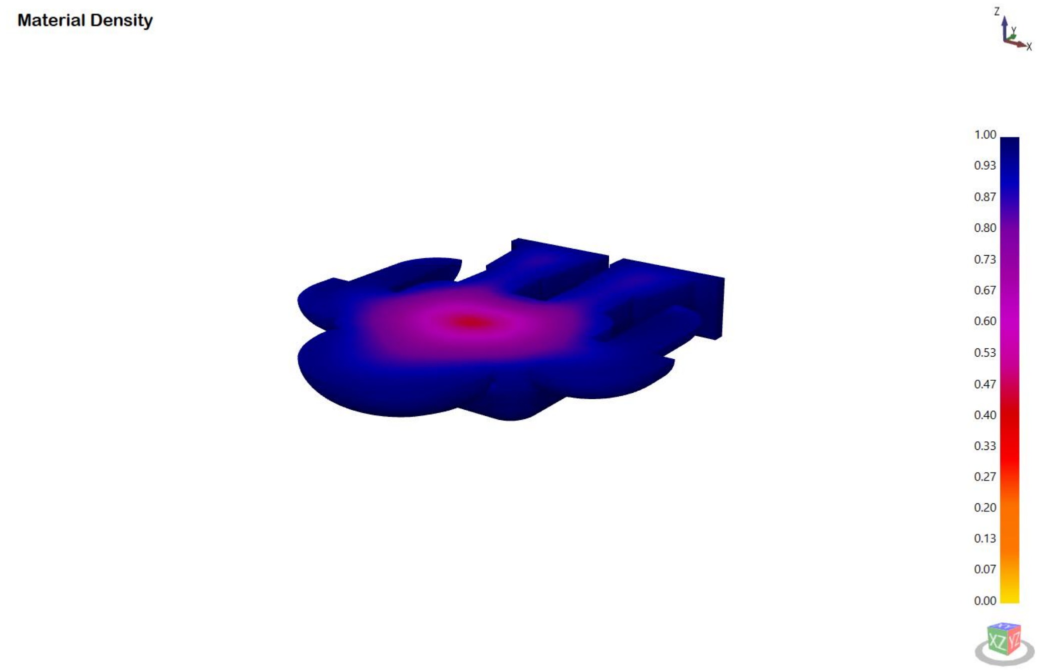

Figure 9: Material density of robot.

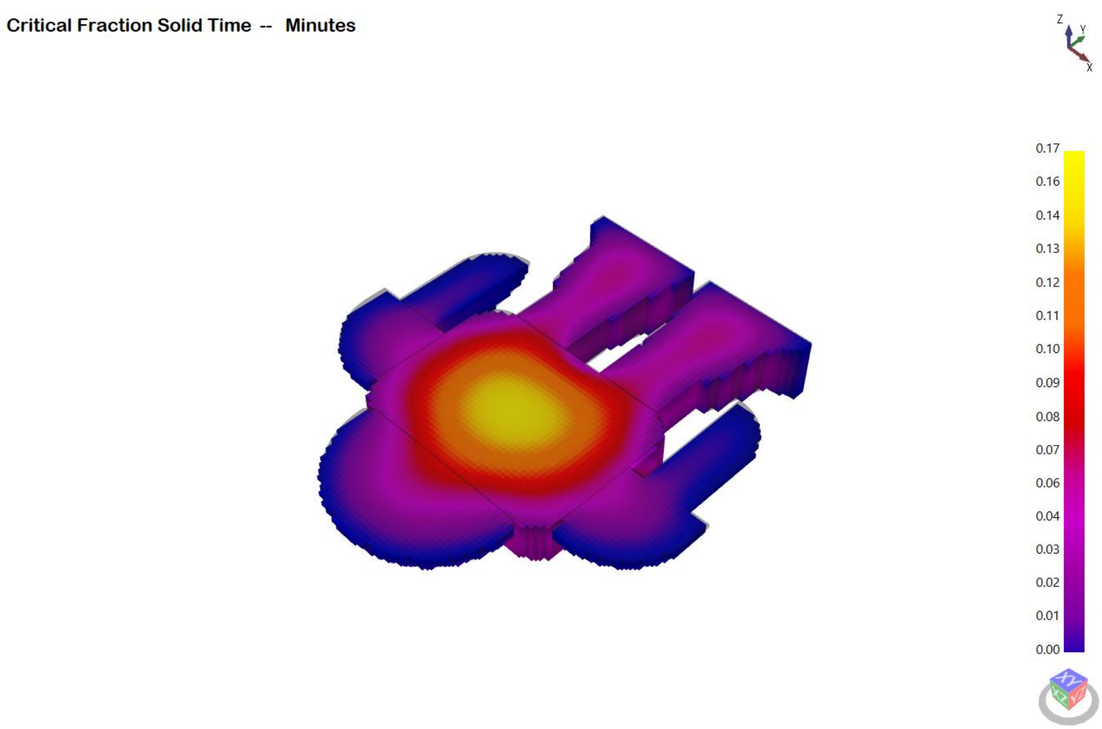

Figure 10: Critical fraction solidification time of robot.

Shown in figures 3 and 4 are the material density and critical fraction solidification time plots for the final design of the robot. The robot has gone through the most changes in this project due to its large volume. The first design was a three-dimensional version which had a thickness that was four times the final design's thickness. This design wasn't ideal since the majority of the robot wouldn't solidify before the runners did no matter how big the runners were designed. The second iteration of the robot was to simply cut him in half to reduce the volume and to make it much easier to cast since his back would be right on the parting line. Though its volume was cut in half, the robot still had a large area which wasn't solidifying before the runner. It was much better than the first design, but the effects due to shrinkage were still apparent and were a large cause for concern due to the large amount of volume left to solidify. Finally, the last design was to scale down the thickness of the half robot by a factor of two. Unfortunately, this didn't completely fix the problem but effects due to shrinkage were greatly reduced compared to the previous designs. Looking at figures 5 and 6, the last point to solidify is in the center of the robot's back, which is where the issue occurred in each design. In the material density plot, the material density isn't full in this same section, which shows that there could be possible defects occurring in this area when casting.

SOLIDCast Combined Iterations

First Iteration

The first iteration of combing the solid cast into one combined model is seen below in Figure 3. After the first iteration all three induvial parts were modified to improve each previous design.

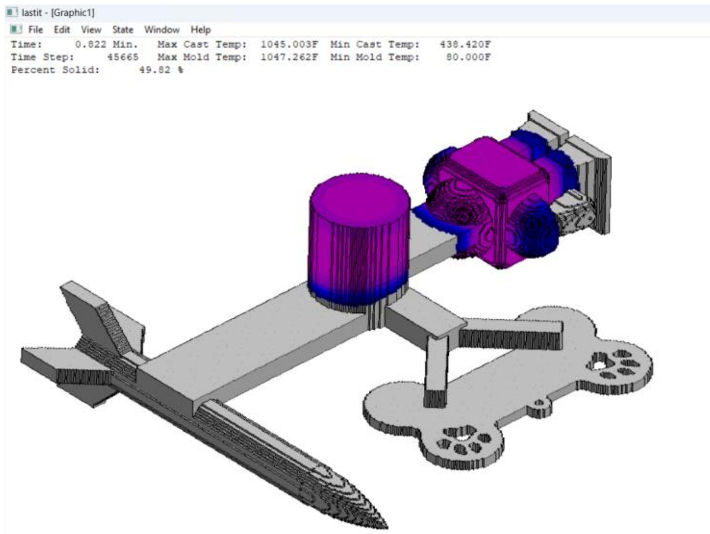

Figure 11: First iteration of gating system and parts combined.

The initial gating system attempt was seen in Figure 1 above. Several issues were identified along the way, most notably was the robot cast in the upper right corner. The robot did not fully solidify during the simulation as the number of nodes used was 400,000 with spacing of 0.025 which was too much detail for the robot but was required for the dog tag and rocket. After running the simulation for over 12 hours which equated to 0.822 min of solidification time in theory, the simulation was ended by the user as the robot clearly didn't work. It should be noted that the critical fraction solid time iso-plot and density plot were not created since this required a finished simulation.

The robot was cube-like, which is not ideal for solidification as it's based on the volume over surface area. The robot's original design had a relatively big volume and small surface area compared to the other parts. The runner was also made to be too small for this part as the runner has fully solidified before the robot. For the next iteration the runner should be made thicker, and the robot should be made thinner.

The rocket was fairly successful, but could have two improvements made. The first would be to make the runner a bit thicker, as the runner started to solidify before the entire body tube of the rocket was solidified. Making the runner thicker will help to keep the supply of aluminum necessary to the rocket, since during solidification it can shrink. The second change is moving the runner closer towards the nose cone as this will center the runner on the rocket. The central part of the rocket was the last piece to solidify so moving this closer to that will be ideal. Also, if possible, moving the rocket closer to the riser will be ideal, as the runner will be shorter, which also helps with the previous problem of the runner solidifying too quickly.

Finally, the dog tag pictured in the bottom right in Figure 1 had a successful simulation as the parts around the paw solidified first and eventually everything solidified, with the parts near the runners solidifying last which is ideal. A potential change that can be made for this part is the runners can be made a bit longer if needed, so the other thicker parts can be placed closer to the riser. Also, since this part had the smallest details around the paws which appeared to solidify properly, the next iterations can be done with less nodes and smaller step size if needed.

Second Iteration

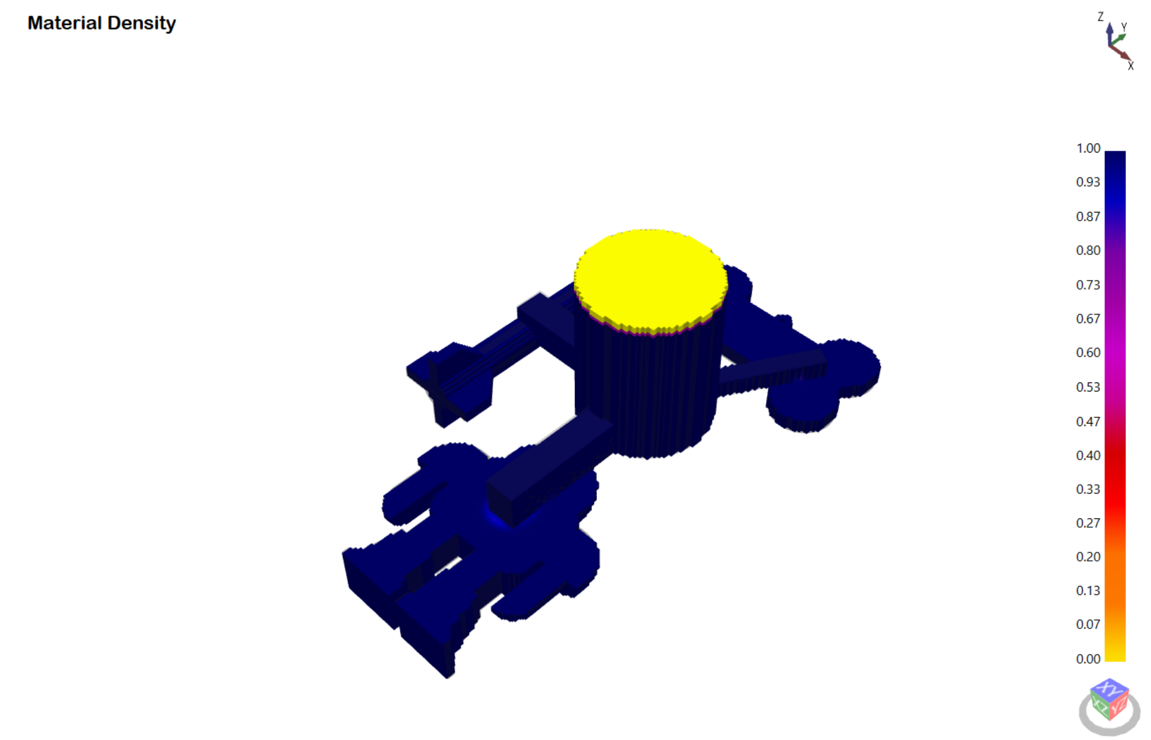

Figure 12: Second iteration material density plot.

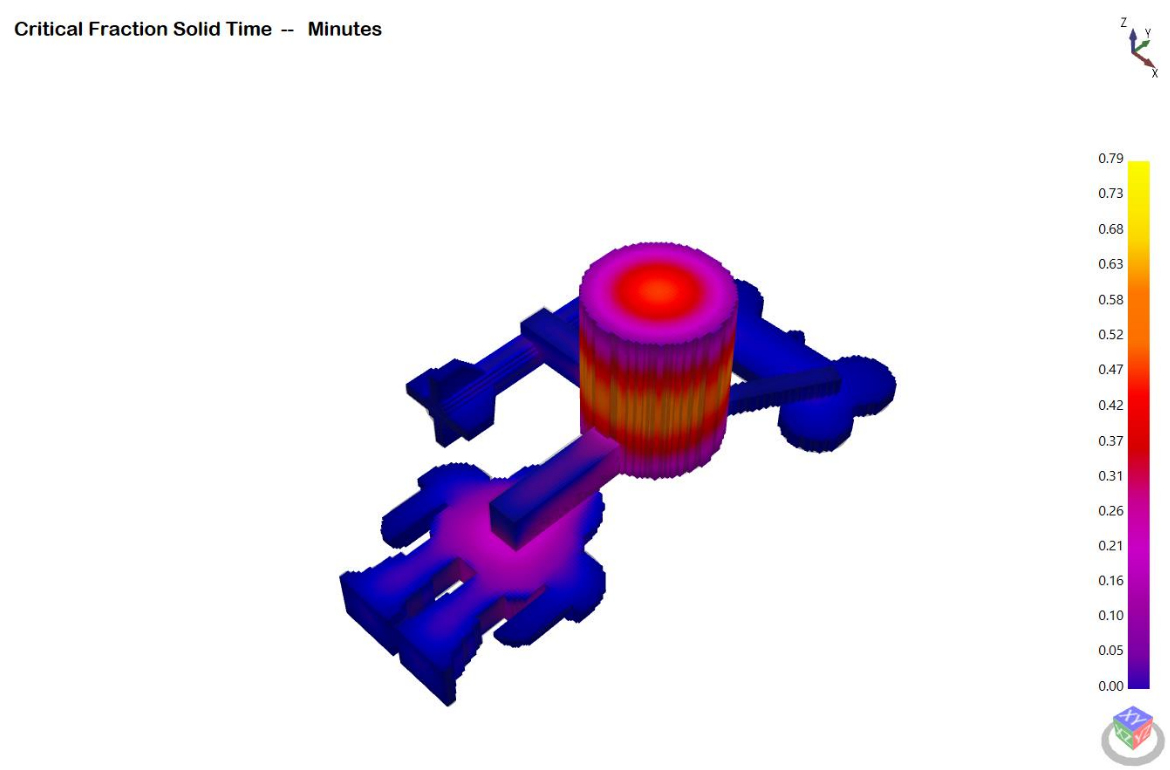

Figure 13: Second iteration critical fraction solidification time plot.

When compared to the first iteration of this design, the second iteration was greatly improved. The first main change was cutting the robot in half. It was re-designed and thinned to make it less cube-like and more conducive to casting. The results of this can be seen in the critical fraction solidification time plot, where the robot solidifies fully, and the last part to solidify is right under the riser. In addition to this, the rocket's riser was moved slightly to solidify at the right location and made slightly thicker as well. Finally, the dog tag was made slightly thicker to ensure it does not solidify before the entire part is filled.

As can be seen in the second iteration plots, the material density and critical fraction solidification time demonstrate a relatively successful version of this model, especially when comparing the critical fraction solidification time to that of the first iteration. This is further supported by the fact that the riser for the rocket is now perfectly placed and solidifies after the rocket which is ideal. However, upon further analysis and "movie" iterations of these plots, some issues were discovered. The runners for the dog tag are in the optimal locations, however, after the first iteration the dog tag has been made thicker, so the runners now solidify too soon. These runners should be made thicker in the final iteration to ensure they solidify after the dog tag does. For the robot, the riser is already very thick and optimally placed, however the end of the riser solidifies before the middle of the robot. The suggestion here is to make the robot even thinner than it is now, as this seems to be the most practical way to ensure proper solidification.

Third Iteration

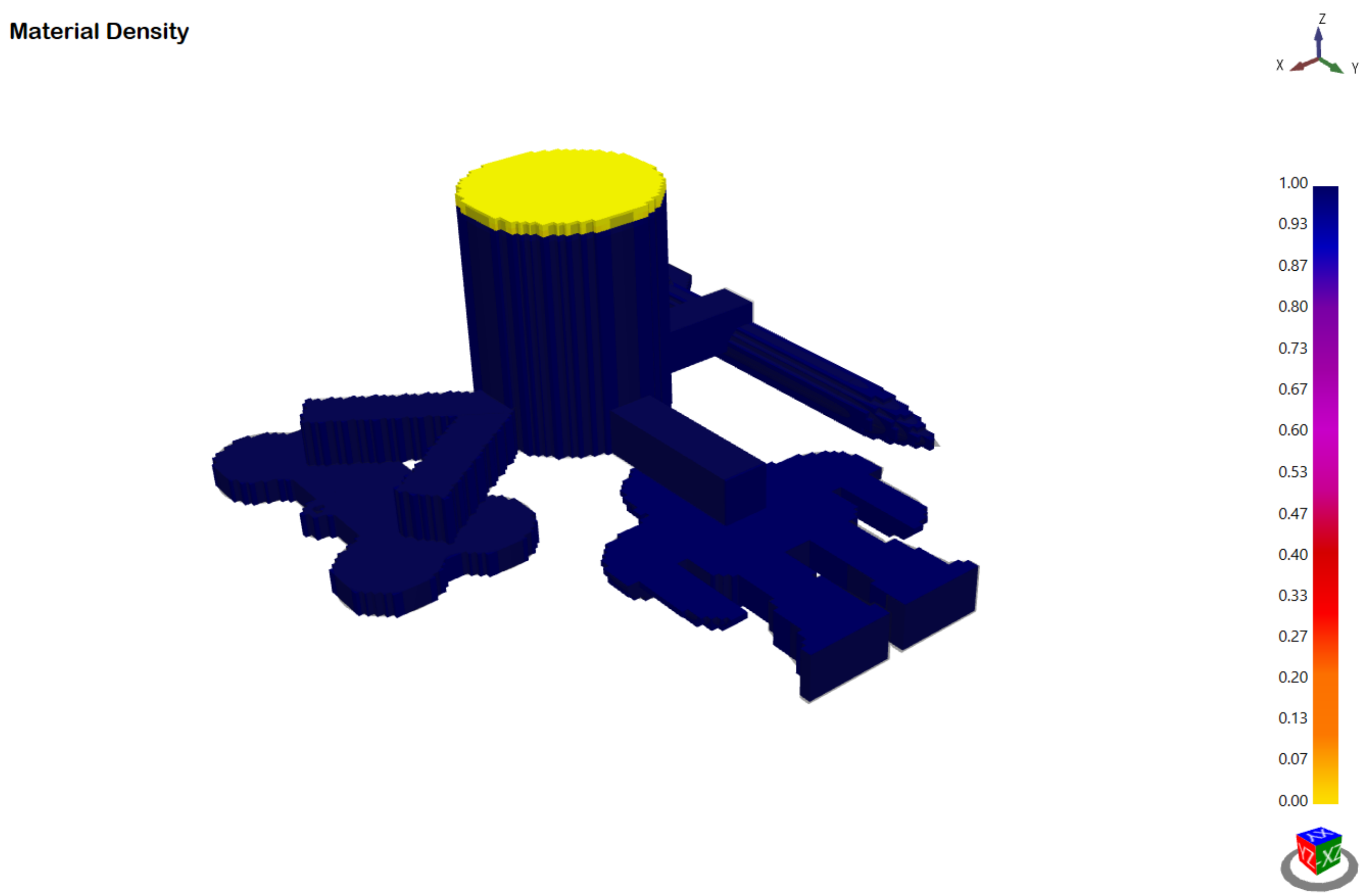

Figure 14: Final iteration material density plot.

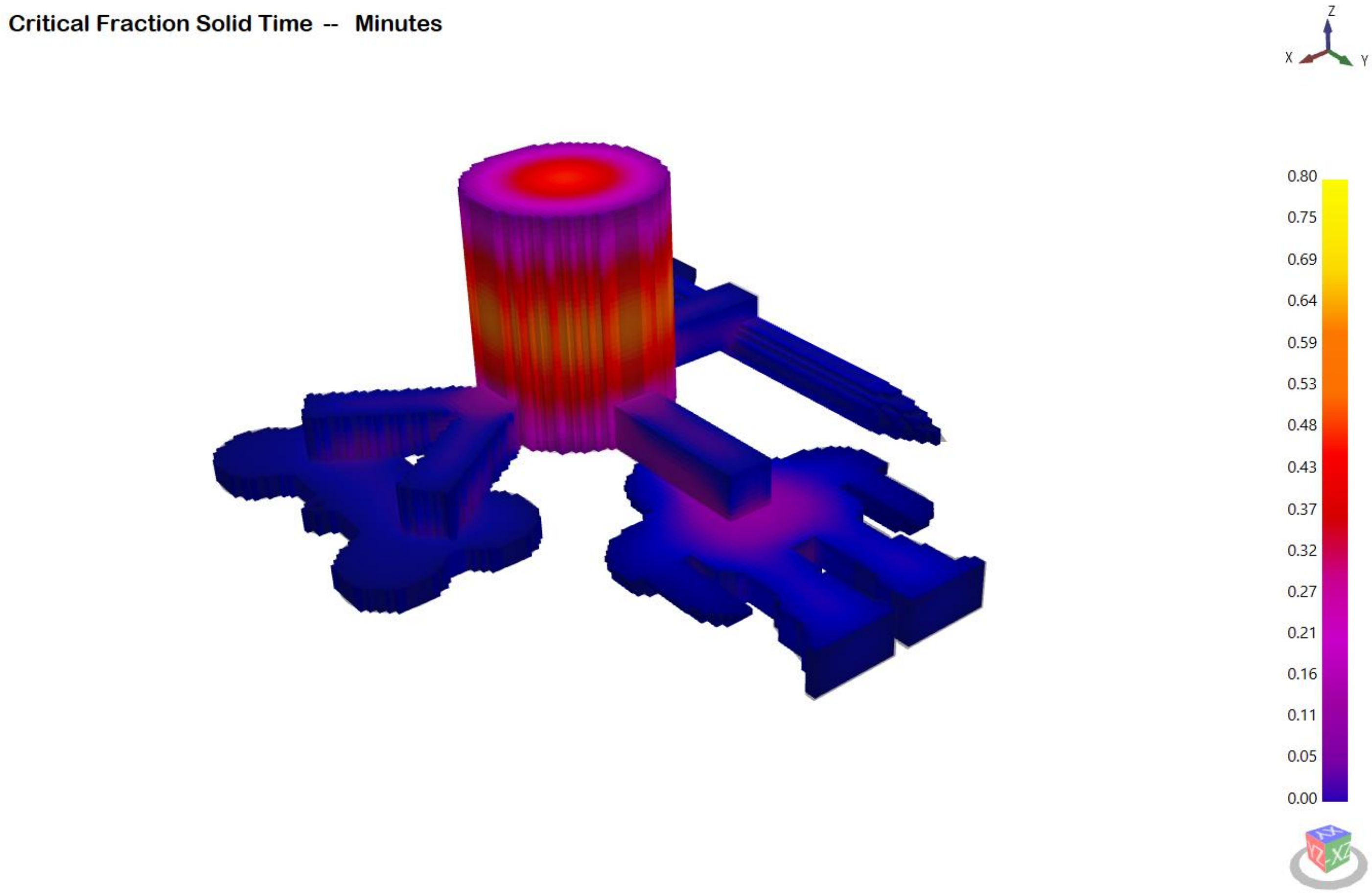

Figure 15: Final iteration critical fraction solidification time plot.

In the final iteration of this casting design, slight size changes were made to improve the castability. The main concern in the previous iteration was the runners solidifying before the parts could fully solidify. This was mainly seen in the robot where its torso had a large portion of it still in liquid form when the runner was solid. To fix this issue, the robot was once again made thinner by a factor of 0.25 so that the volume to area ratio of its torso would be reduced. In addition, the runner was made slightly bigger and covers more of the robots back compared to the previous iteration, so that it takes longer to solidify with respect to the robot torso. Though it still isn't perfect, the effects due to shrinkage will be reduced in the robot's back. Otherwise, a few more changes that were made were to make the runners to the dog tag and rocket slightly bigger, about 0.2 inches in the height and width, to overcompensate for solidification of the parts before the runners.

Looking at the material density and critical fraction solid time plots in figures 10 and 11, they show better success to the cast compared to the previous two iterations. Looking at the material density plot, each component in the design reaches full density, which is to be expected. Looking at the critical fraction time plot, both the dog tag and rocket fully solidify before the runners do, which proves that the increase in runner size has helped to feed the parts to reduce shrinkages. However, when looking at the robot model, it still has an intense purple in its volume meaning it still hasn't solidified yet. To visualize whether or not the part solidifies before the runner, a snapshot was taken shown below in Figure 16. As shown in the figure, the robot unfortunately doesn't fully solidify before the runner does. Though it isn't the ideal situation, it is much better than the previous iterations. To try and fix this issue, the robot would have to be very thin, or the runner would have to be outrageously large. Since these changes aren't realistic to the cast, the issue stems from the design of the robot. If the robot were to be redesigned, the torso size would ideally be smaller to reduce the volume to area ratio which will improve the cast of the robot. But since these issues stem from the geometry of the robot, no further iterations of runner sizes would fix the shrinkage effects of the robot without being unrealistic.

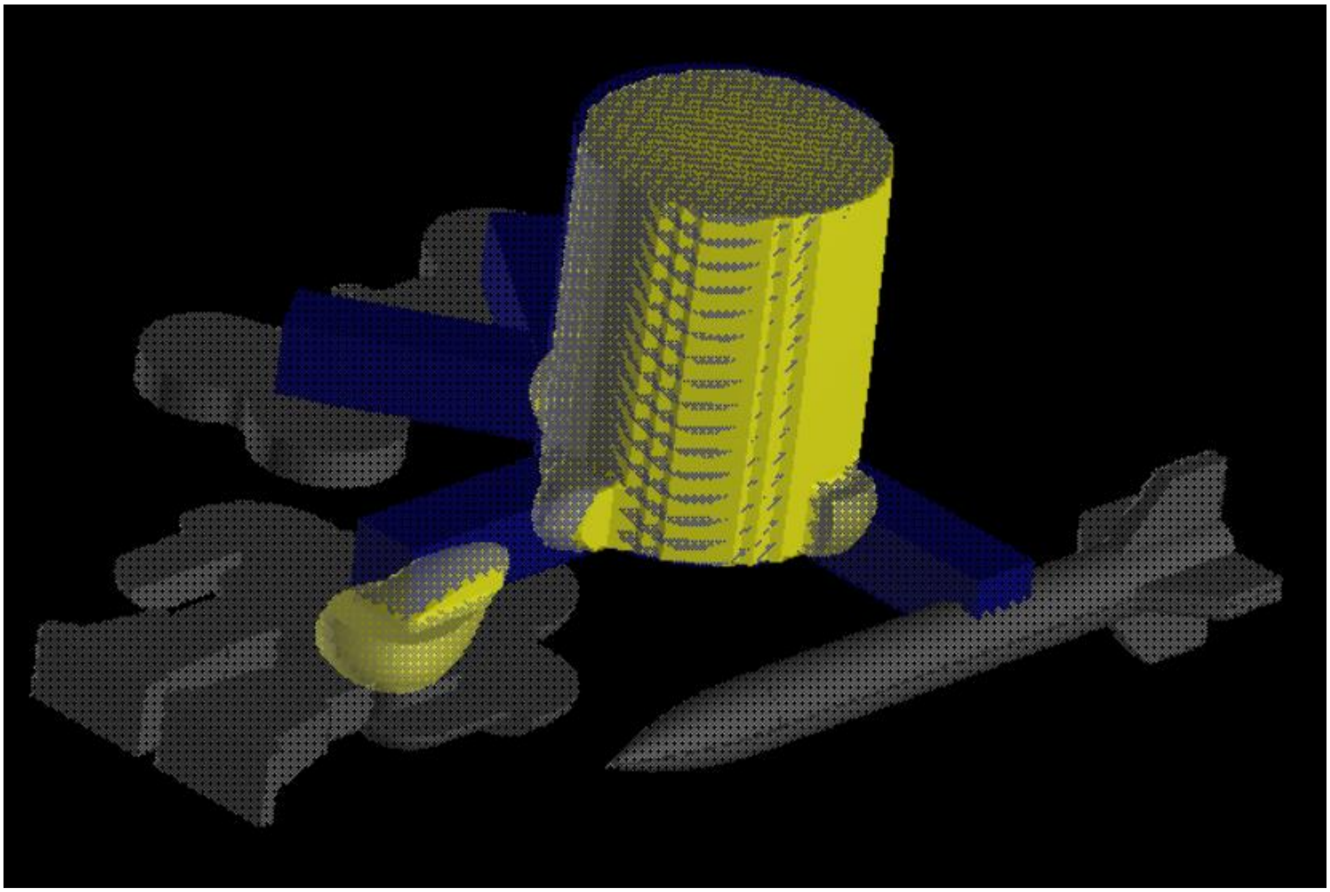

Figure 16: Snapshot of final iteration.