

ME 391: Independent Study

Summary Report

The CNC Hollow Knight Project:

CNC Aluminum Action Figure of the Knight from the game *Hollow Knight*



Tristan Linn
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Goal and Description:

The CNC Hollow Knight Project is to recreate the titular character, "The Knight" from the popular 2D indie video game, *Hollow Knight*; a game where you explore a vast ruined kingdom of insects and heroes. The goal of this project is to create an aluminum poseable action figure that resembles The Knight by using cnc technologies.



Final Deliverable:

The final deliverable for the CNC Hollow Knight Project is one poseable action figure resembling The Knight. The overall dimensions are 4 x 2.75 x 1.5 and the figurine can be seen below.





Total Time Breakdown:

A total of 212 hours have been spent on the CNC Hollow Knight Project. A breakdown can be seen below. A full breakdown and timelog can be found at:

Time Log:

https://docs.google.com/spreadsheets/d/1h6t7Zz3BfDQjicnRH_AyJsmAcl-JflvWeXgBm7UlfqU/e/dit?usp=sharing

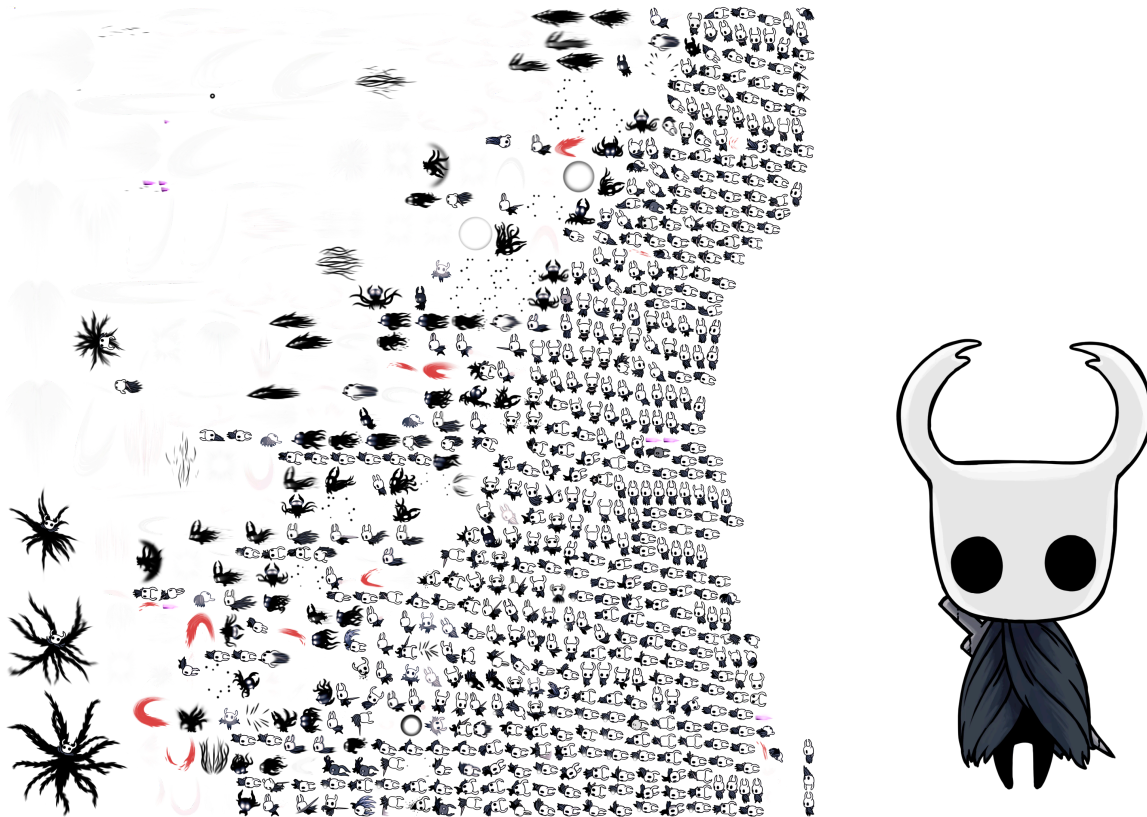
Breakdown	Hours
Conceptualization	17.77
Premodeling (Blender)	46.67
CAD	29.30
CAM	39.13
Machining / CNC	33.60
Armature Testing / Cad Revisions	36.90
Docs & Logistics	8.97
Total Time	212.33

Work Process

The project follows four main phases: Conceptualization and Premodeling, CAD of Main Geometry, CAM and CNC, Armature Creation and Assembly

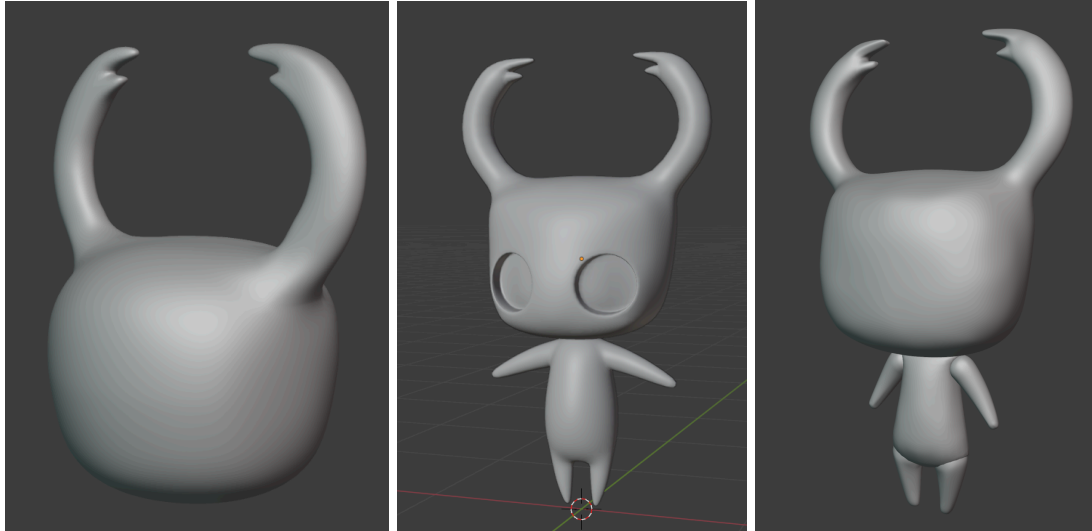
Conceptualization and Premodeling (Blender):

Given the fact that *Hollow Knight* is a 2D video game the only references I had for a 3d model was the in game sprite sheets and promotional art. However, the artwork only had the front and back views of The Knight and never showed under the Knight's cloak, so artistic liberties were taken.



Blender Pipeline

Due to the round and organic nature of the Knight, Blender was chosen to create the overall form and 3D geometry. The model was first created from a sphere and two cylinders and then vertices were manually adjusted and inserted using edit mode. The grab and smooth tools in the sculpting tab were then used to make minor changes. The modelling first focused on the head shape of the Knight before focusing on the body proportions and then machinability and function. To get ready for importing to fusion the limbs and head were made to be closed, smooth, objects with no holes, before being exported as obj files.



Importing to Fusion

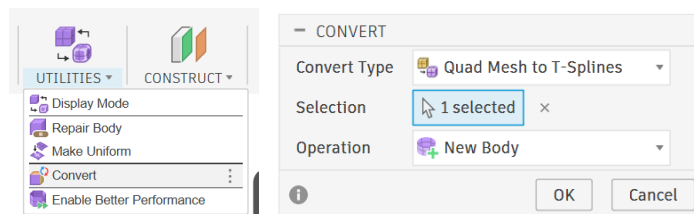
The limbs, torso, and head were all imported into fusion using the following method:

Obj > Quad Mesh / Surface Body > T-Spline / Form Object > Solid Body

Once the objects were turned into Form Objects, minute changes were made to ensure machinability, such as making the small internal corners of the horns larger to accommodate for a 1/16 BEM. Other considerations were made such as applying smoothing and tweaking the surfaces to be more round. Once final adjustments were made, the forms were finished.

The steps to get obj files into editable Fusion 360 Solid Body:

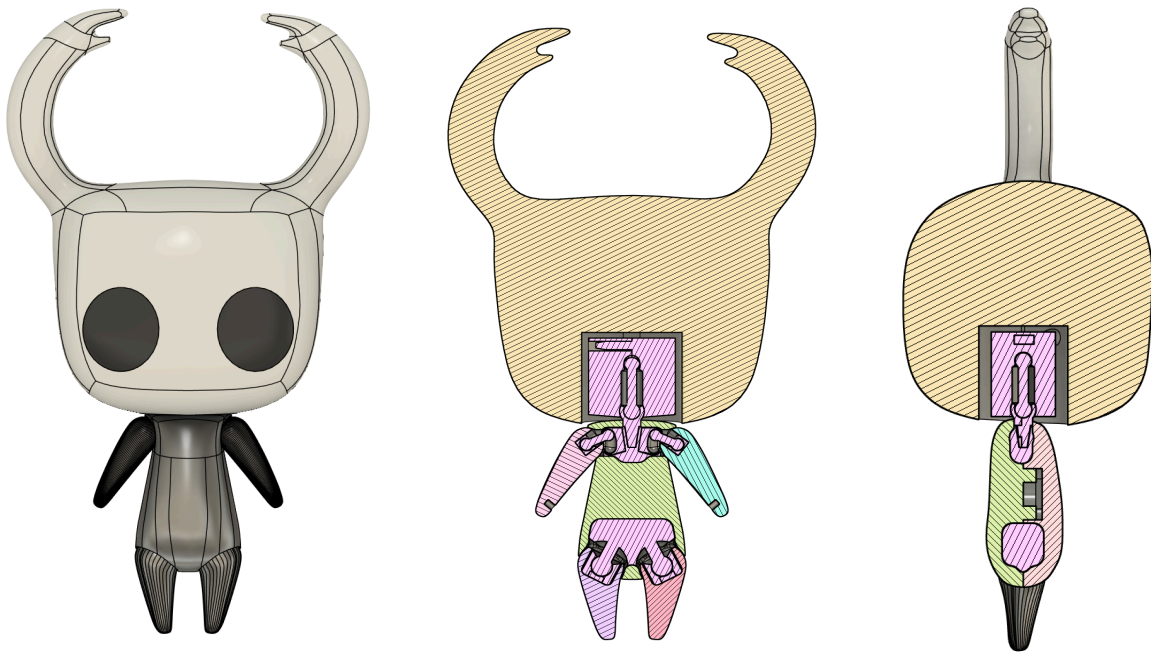
1. The obj files were imported into blender using the import mesh tool in the Mesh Tab.
 - a. This imports the obj as Quad Mesh.
2. Create a new form under the Surface Tab. **Select the surface body from step one in the Browser Window.** Then go to utilities and select convert.



3. Edit the T-Spline Form Object until desired geometry is achieved.
4. Click Finish Form to convert into a solid body.

CAD of Main Geometry

The main geometry CAD focused on making the internal fits for the resin printed cores that would allow for articulation. To this end, holes were cut into the limbs, and cavities were made in the torso and head. The torso and head were also split into multiple parts; the torso into two halves, and the head into a skull and sockets. The joints are all ball sockets and all forms of fastening are press fits. All sockets were split vertically in half with guiding slots and tabs to be press fit around each ball joint. The assembled sockets would then be pressed into their corresponding hole.



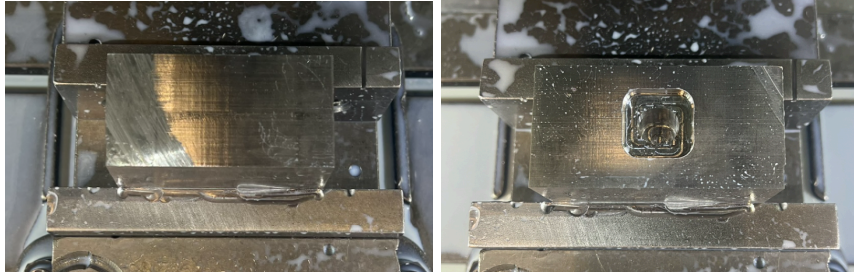
CAM and CNC

The CAM was split into two parts, the head and then everything else. The head used a stock of 3.495 x 3.499 x 1.767 and the limbs, torso, and eyes used a stock of 4.509 x 4.513 x 1.32 (Note a second stock of 2.504 x 1.008 x 4.55 was used after a wax holding failure, see Appendix A for more details). A total of 12 tools were used ranging from 0.5 FEM down to a 1/16 FEM and 3/16 BEM to 1/16 FEM with two drill bits for cavities in the holes a #7 and #40. The stock was faced and squared on a manual milling machine. In order to hold the organic forms in a safe manner, machinable wax was used between workholdings to backfill the machined cavities. The wax was then melted out and the parts washed after machining.

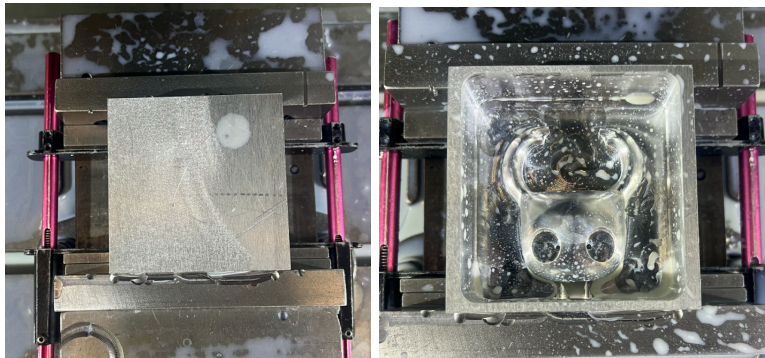


There were a total 10 workholdings, 4 for the head and 6 for the limbs. The head was as follows: neck hole, front side, wax facing, back side.

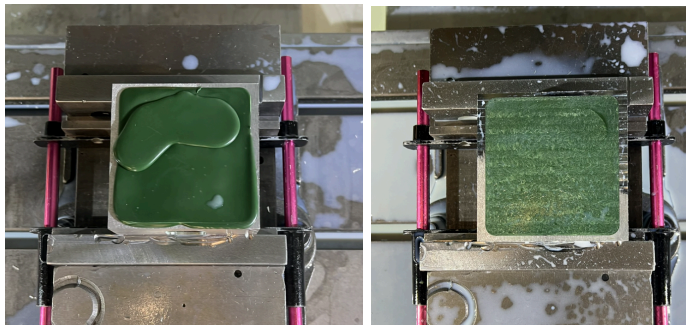
Neck Hole



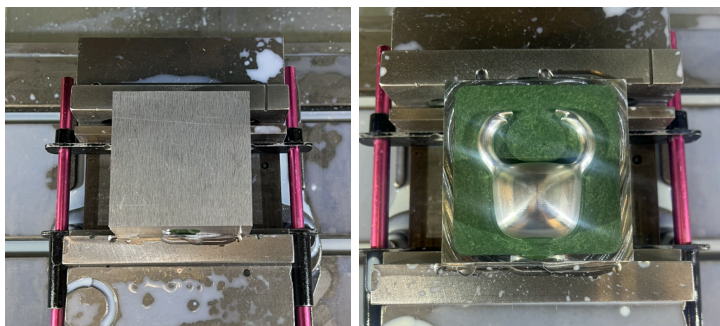
Front Side



Front Side Wax Facing

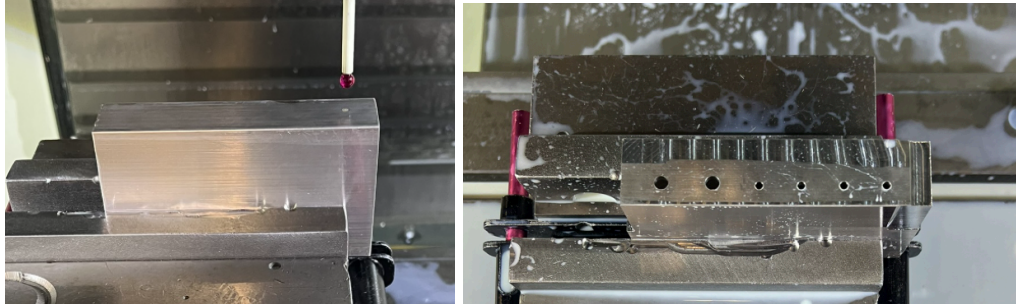


Back Side

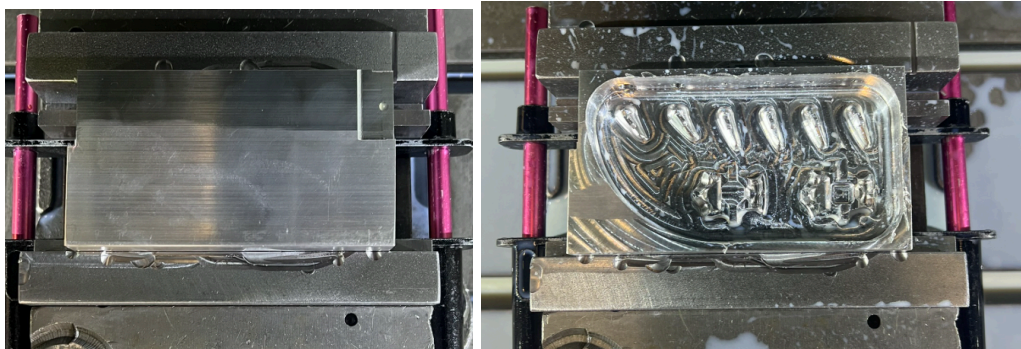


The limbs, torso, and eyes workholding are as follows: socket holes, front side and interior torso, front wax facing, back side and exterior torso, back wax facing, front side tab removal.

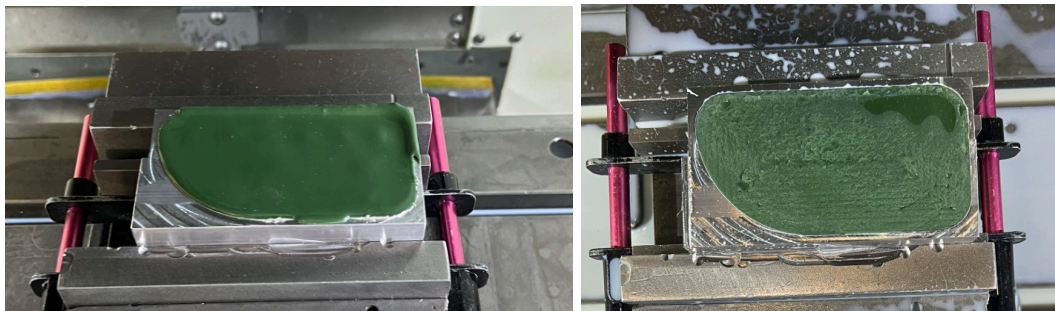
Socket Holes



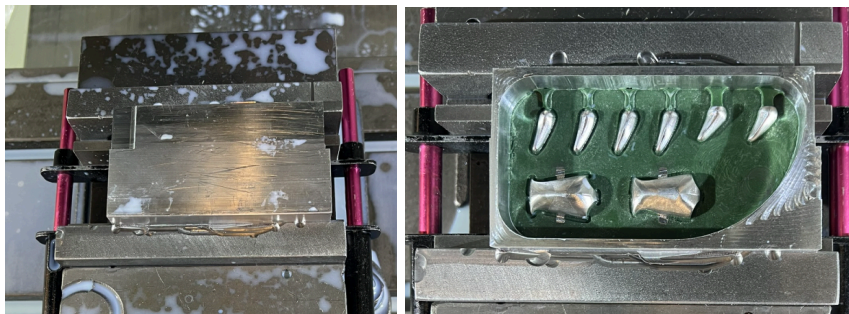
Front Side and Interior Torso



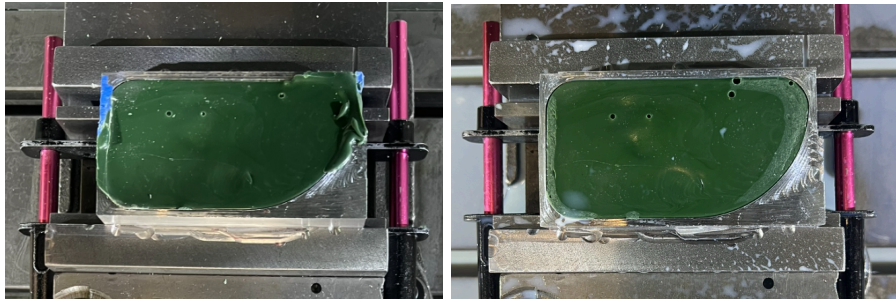
Front Side Wax Facing



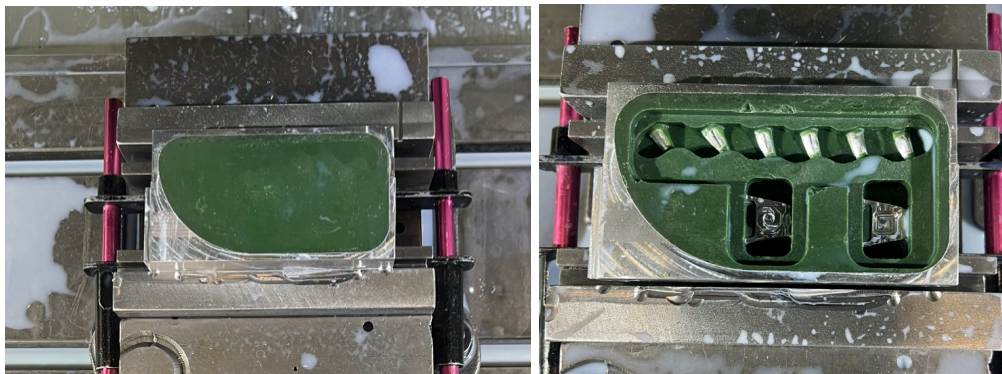
Back Side and Exterior Torso



Back Side Wax Facing



Front Side Tab Removal

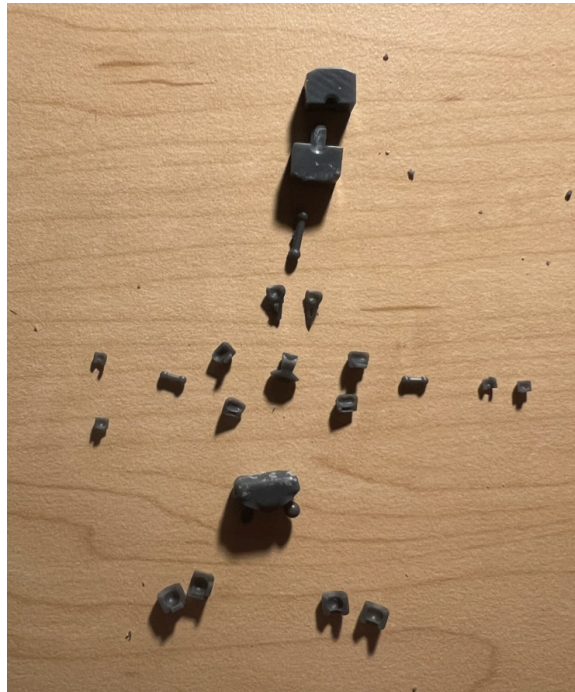


Oil Washed Machine Parts



Resin Printing, Armature Testing, and Assembly

After the outer aluminum shell of the action figure was machined. Time was spent refining the internal resin printed joint armature that allowed for articulation. Overall there were 5 ball joints and the following sockets and parts: a leg ball socket, an arm, ball socket, the hip ball joint torso core, the neck torso core, and the head socket. An exploded view can be seen below:



Tens to hundreds of parts were printed iterating the fits of these joints for assembly.



These parts were not particularly complicated, but the complexity lied in the scale of the model. The smallest part was half of an arm ball socket that would be pressed into the opposite half. This part was smaller than a grain of rice and would later be inserted into the arm limbs of the Knight.



The assembled ball joints before being pressed into their respective limbs.



Assembling the Knight

1. Insert the legs onto the hip torso core.



2. Insert legs and hip core into the Back Torso



3. Press the shoulder blade (revolute joints for the arm limbs) around the ball sockets of the arms.



4. Construct the neck ball socket and insert the neck ball socket into the torso core.



5. Place the limbs and cores into their respective positions.



6. Insert front torso onto back torso and press together



7. Attach Head to torso. The Knight is now complete.



Outcomes

Overall, the CNC Hollow Knight Project was a success. A poseable cnc aluminum action figure was designed, modeled, and machined. All limbs and head have articulation and the surface finish is of high quality. The head has no offsets and superb finish. The limbs have a minor offset but quality machine finish. The articulation achieves desired range of motion and holds position nicely.

Lessons Learned

Waxholding

Waxholding had its learning curve, parts were lost, and it took two attempts to machine the limbs (See Appendix A). However, overall, the waxholding worked. Though, the limbs have minor offsets from the tab removal and waxholding slipping.

Because both sides of the stock block were waxed, the machine wax was able to slip vertically out of the stock and had to be hammered back in and flattened. **In the future a locking shelf using either a t-slot cutter or FEM to cut a groove midway or shelves on either end of the wax volume would stop sliding out of the stock. Further, parts should have tabs or sufficient surface area in all axes when being workheld by wax.**

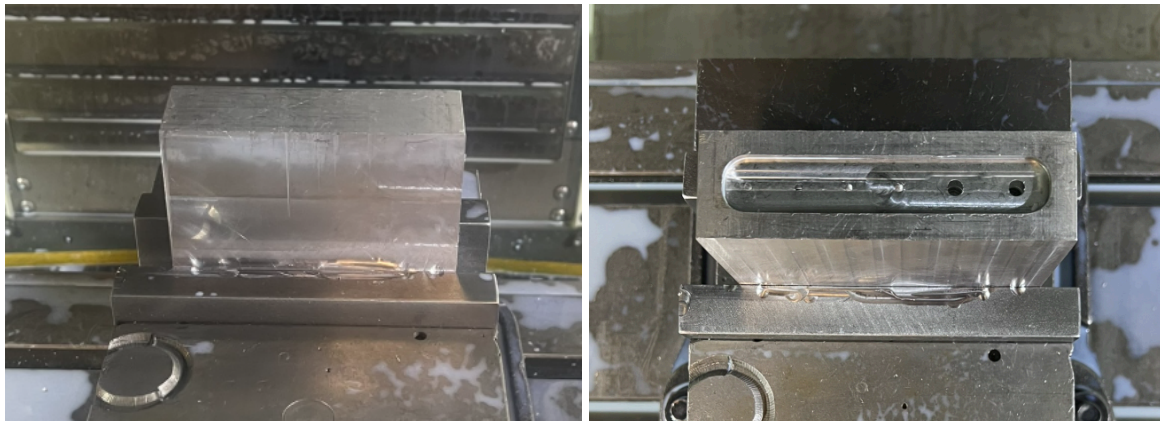
Articulation

Articulation is functional, however the arms joints are slightly looser than desired. Arms hold position, but can be pulled out of their socket. To fix this in the future the upper articulation should be constructed in a smaller housing enclosure and that enclosure inserted into the torso. An alternative would be to dial in the ball joint length with more testing. However, time did not allow for this to occur.

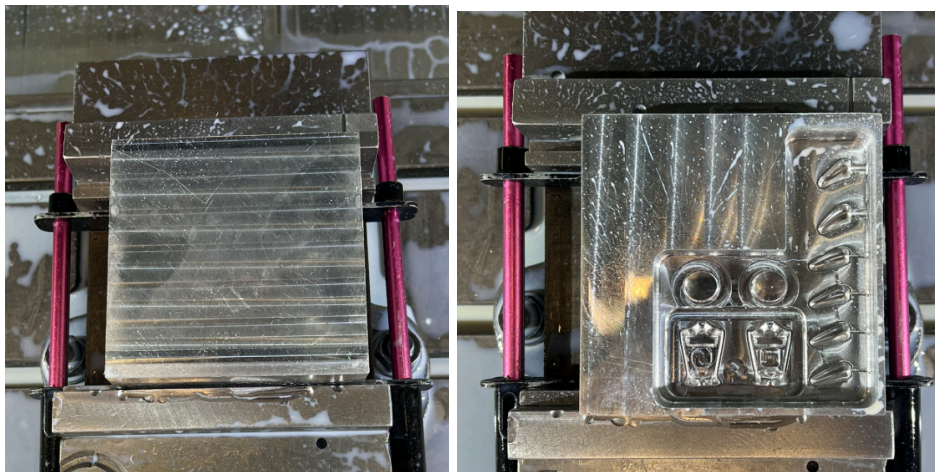
Appendix A: Wax Fail of Limbs and Torso (No Tabs)

During the first machining attempt of the limbs, torsos, and eyes a holding failure occurred. The initial parts were being held down by the wax filling the socket holes and cavities in the geometry. This was useful in securing the x, y, and z axes separately; however this did not account for multi-axial movement. A gap in the wax, alongside the spindle speeds and feedrate, allowed the limbs to climb out of their holes and fall out of the machine wax. This resulted in the failed machining of workholding 4. However, I was able to salvage the remaining parts securely held in the wax, and took this incident as an opportunity, by adding tab anchors to the limbs for the second attempt of machining these parts. This allowed the parts to be held securely deep within the wax during the second attempt.

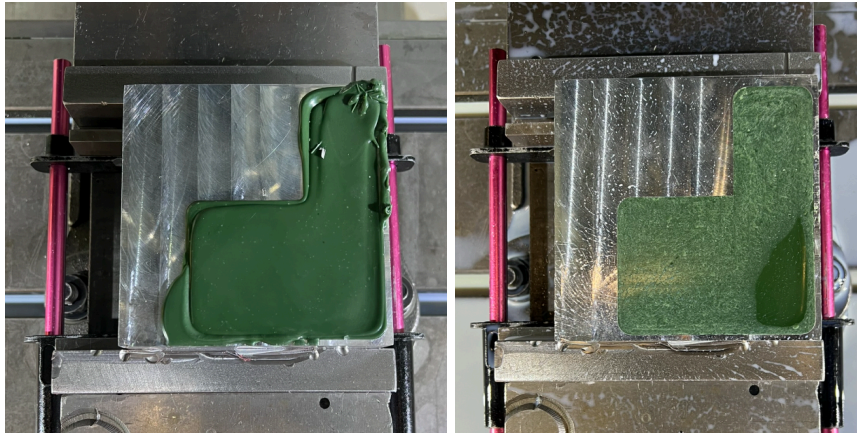
Socket Holes



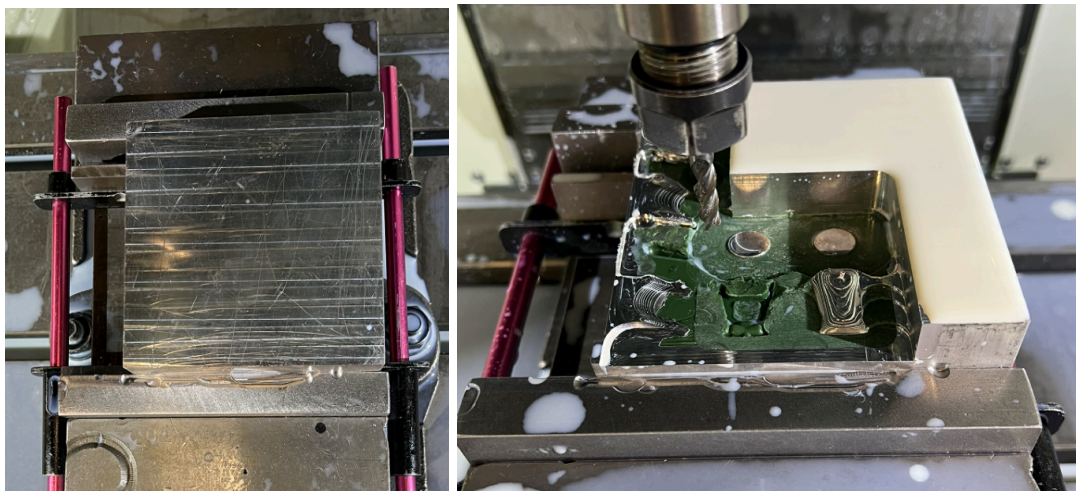
Front Side



Front Side Wax Facing



Back Side and Wax Holding Failure



Salvaged Parts

