

DSGN 348: Final Project

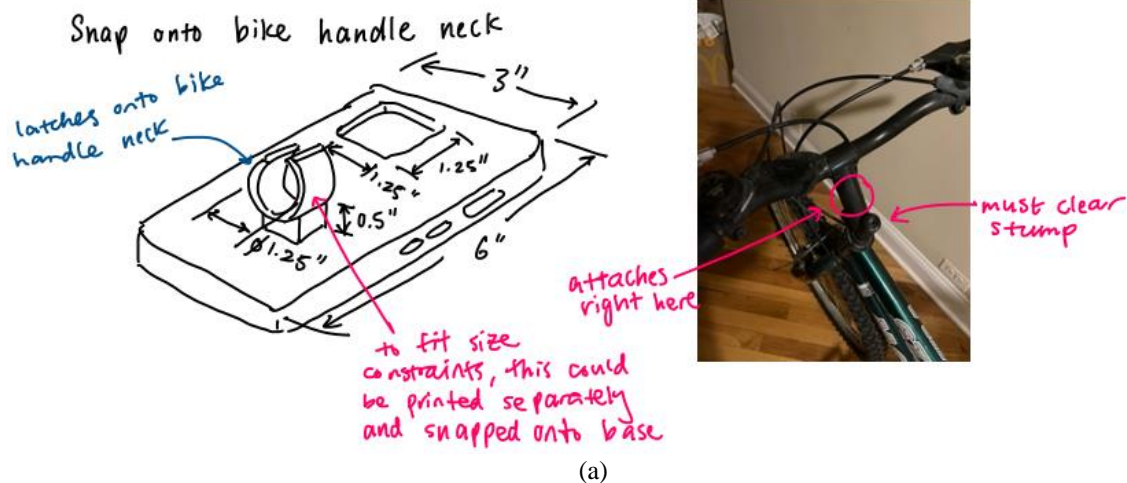
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1. Introduction

Additive manufacturing (AM) is the process of building up an object layer-by-layer. This is opposed to conventional methods, which remove material to form a shape. Additive methods have the advantage of not needing design-specific tooling (such as specific drill bits, molds, etc.), meaning a single machine can easily print different geometries without much physical changes between prints. Without the constraints of tooling, AM can also create much more complex geometry than conventional methods. These reasons makes AM a very good tool for rapid prototyping. This project utilized AM to create a phone case. This phone case went through several iterations based on user feedback. The machines available for this project were the Formlab Form2 (SLA) and Objet Connex (Polyjet).

2. Model Development

Preliminary ideas for what to create included a phone case that can attach to a bike handle (see Figure 1a), a phone case with a cardholder (see Figure 1b), and a phone case that has a built-in stamp (see Figure 1c). The first option was ruled out because it did not fit into the requirement that the phone case not have protrusions greater than 0.5" in any direction. Additionally, testing such a case seemed dangerous for whatever phone used. Thus, the latter two options were further explored. After a discussion with Professor Beltran, I decided to combine both ideas, such that there was a stamp on the top of the phone and a cardholder on the back. I was reminded of how my grandma always carried around a stamp with her name on it to sign documents, and decided to put a stamp on the top of the phone with my name.



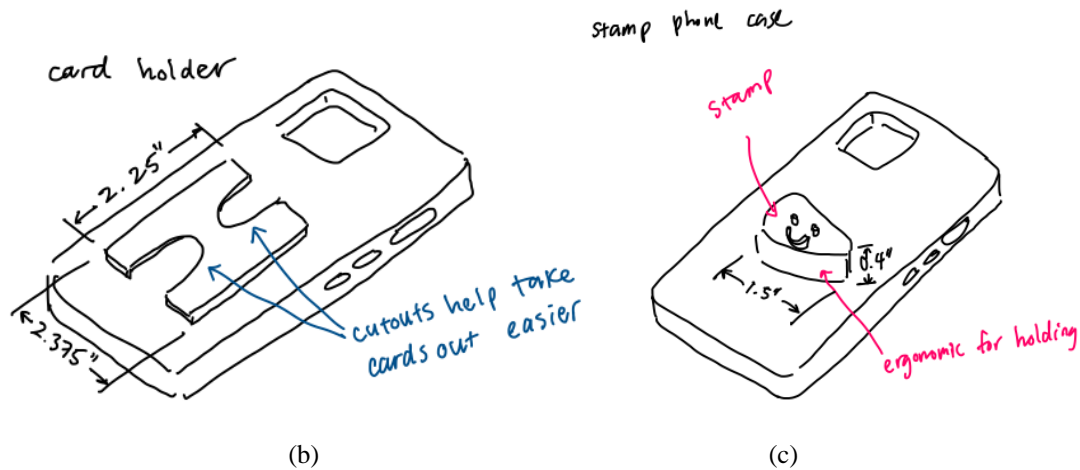


Figure 1. Preliminary phone case ideas: (a) bike handle phone case, (b) cardholder phone case, and (c) stamp phone case.

I used SolidWorks to create the 3D model. I found an iPhone 12 model on GrabCAD and took measurements of major dimensions of my phone to make sure this model was accurate. A couple of early design decisions included making the cardholder into an “X” shape. This allows the user to push a card up from the bottom, while also making it look more interesting compared to typical cardholders. The cardholder also has a small nub on the inside to pinch the card to the case. I also made the decision to have a bumper around the camera because the iPhone 12 cameras protrude a lot out of the phone, and I wanted to protect this. I also decided to only have the phone case fold over the phone at the corners to hopefully make putting in and taking the phone out of the case easier. The final CAD model is shown in Figure 2. A lot of other features were added after user testing and will be discussed in the next section.

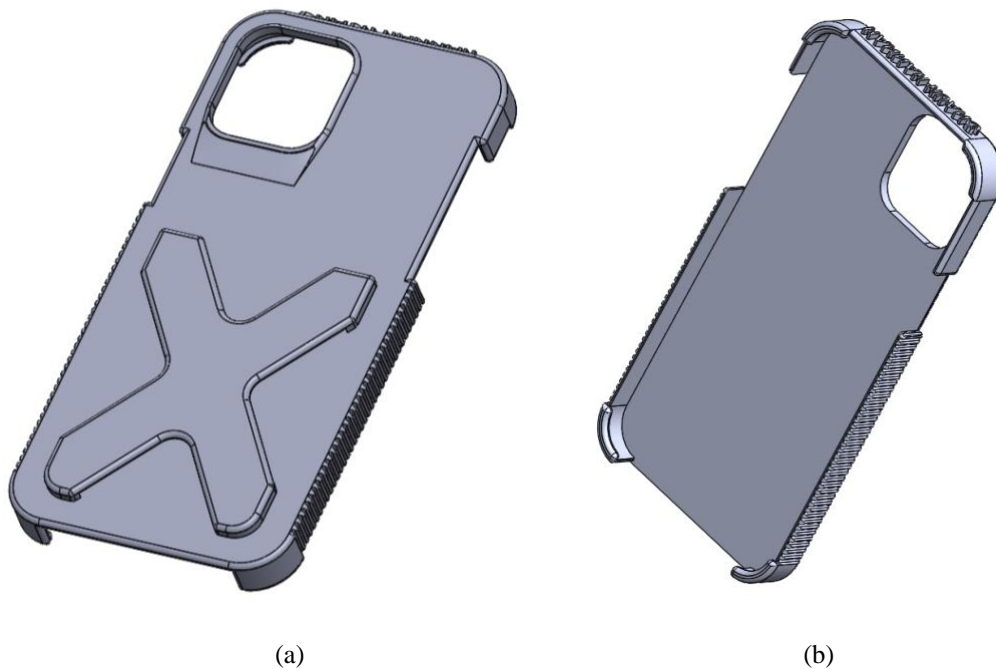


Figure 2. (a) Front and (b) back of the final phone case.

This design benefits a lot from additive manufacturing. First, the small features that make up the text on top of the phone and the finger grips on the side would be almost impossible to machine out with a drill, especially the sharp internal angles of the letters. Next, the cardholder being made as part of the same body as the phone case makes this virtually impossible to injection mold. The small features would also likely be lost if injection molded. However when 3D printed with the right machine, this case is not too difficult at all. Because of the cardholder, I decided to use the Form2 instead of the Objet. This is because most orientations of the case would lead to copious amount of support material, a lot that might be very difficult to get rid of if between the cardholder and case. Additionally, I wanted to use Tough 1500, which would give me a little bit of flexibility to bend the case when putting it on or taking it off of my phone, but being rigid enough to be fully secured to the phone when on. When printing the case, I took care to not put supports on the stamp side of the phone, or else it would lead to rough surface finish and make it difficult to use the stamp.

3. Iterations

The first iteration of the phone case was printed with Tough 1500 on the Form 2, using 0.05mm layer thickness. The first phone case iteration served to test out the fit of the case on the phone, along with the cardholder (see Figure 3). I could not take pictures of the case on the phone, but the case snapped to the phone well on the front. However, there ended up being more than a 1/16" of space within the case for the phone to move around. Additionally, the camera did not properly align to that of the phone. A card fit into the cardholder very snug. However, it seemed like there was too much pressure to put the card into the cardholder. Over repeated use, I could imagine that this would cause the card to become damaged. The stamp came out very clearly, which I was surprised by. The sharp corners and holes in the A's are very well defined.

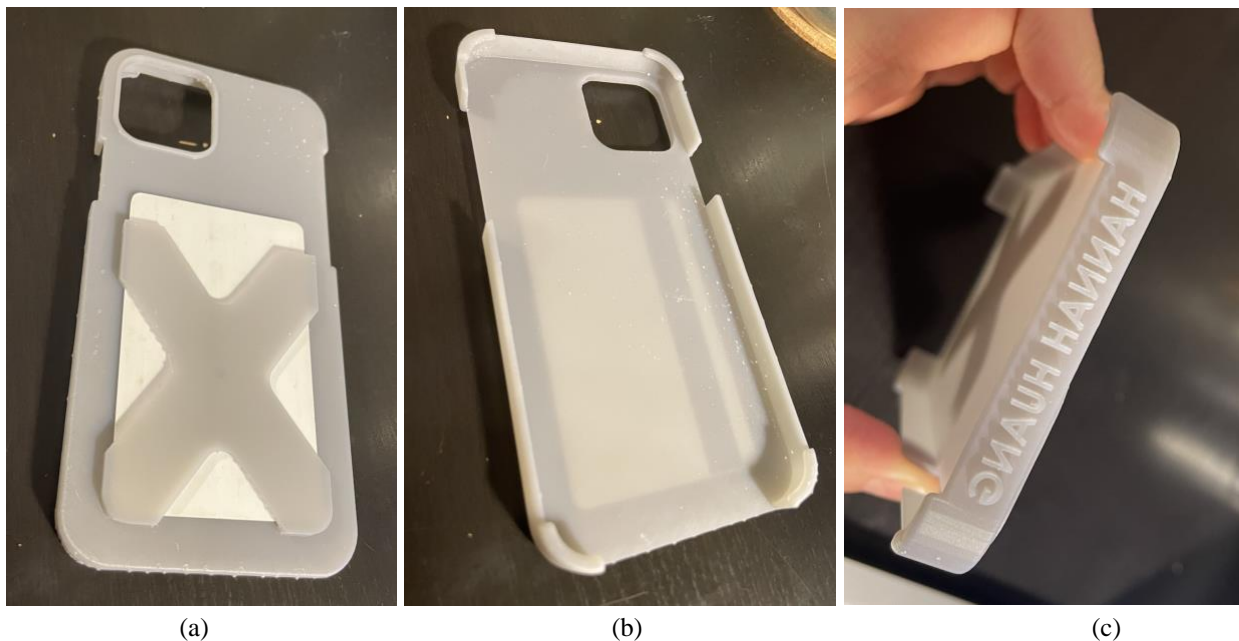


Figure 3. First iteration of phone case, showing the (a) back, (b) front, and (c) stamp.

For the second iteration, I continued to use the same settings and material as the first iteration because of how well everything snapped onto the phone the first time. The second iteration of the phone case fixed the misalignment issues with the camera. I also decreased all clearances I had in the initial iteration. This allowed the case to fit almost perfectly to the phone. I also decreased the size of the nub on the inside of the cardholder, and a card was able to slide in much easier, but still feel secure. Figure 4 shows the second iteration of the phone case, which has very subtle changes from Figure 3, since all the changes were to improve the fit.

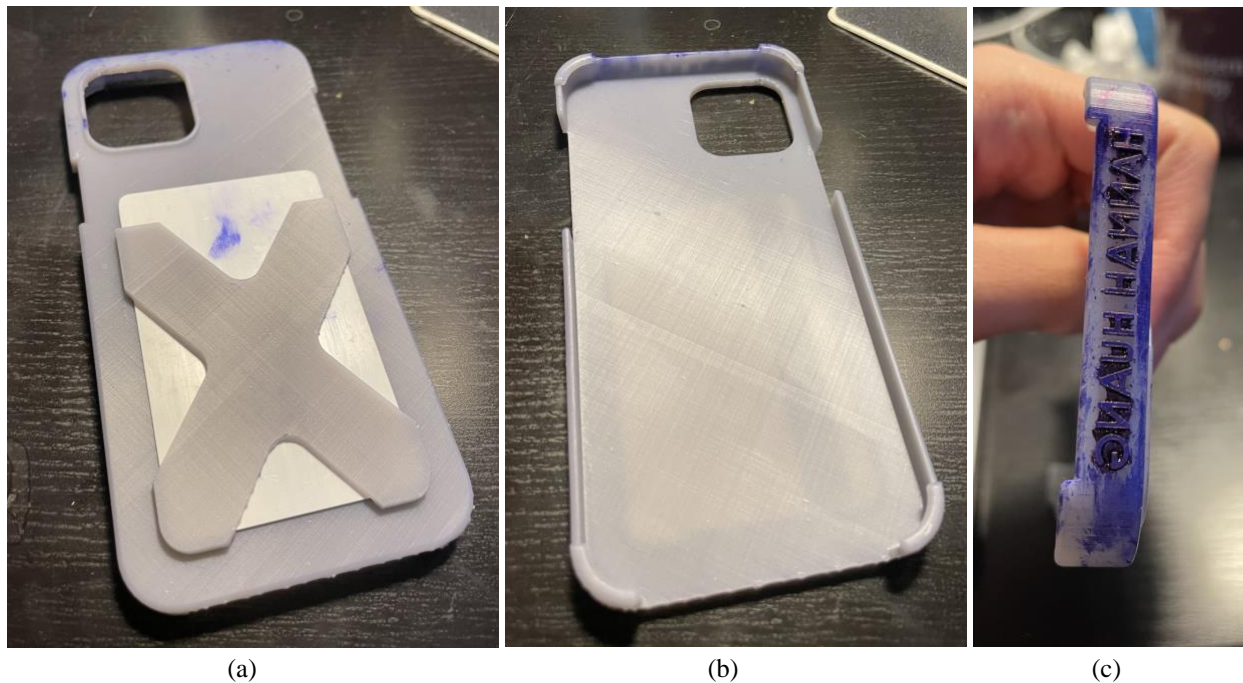


Figure 4. Second iteration of phone case, showing the (a) back, (b) front, and (c) stamp.

Iteration 2 of the phone case underwent user testing. I focused my questions on the parts of the phone the users would interact with the most. This included questions on the overall hold of the phone, as well as questions regarding the cardholder and stamp. The questions were as follows:

1. On a scale from 1 to 5, how secure does the phone feel in your hand?
2. On a scale from 1 to 5, how easy is it to use the cardholder?
3. On a scale from 1 to 5, how easy is it to use the stamp?
4. On a scale from 1 to 5, how clear did the stamp turn out?
5. What else do you like or dislike about the case (aesthetics, ergonomics, etc.)?

The responses are shown in Table 1. The resulting stamps from testing are shown in Figure 5a. Note that the stamps were done by extracting the ink from a pen and not with an ink pad. This could alter the quality of the resulting stamps. There were a lot of recurring issues brought up by users, such as the slippery feel of the case, as well as the interference of the

camera bumper with the usability of the cardholder (shown in Figure 5b). The stamps ended up coming out better than expected, but it was still not great. However, it validated for me that Tough 1500 was not too rigid for the stamp. There were other responses from users that were conflicting, such as some people liking the “X” cardholder design, while others didn’t like the design. I noticed that even though the bottom cutout has the intent of letting someone push a card out, not everyone used it and said they struggled to take the card out of the top. There were also conflicting opinions on the case only folding over at the corners. There were also a couple comments regarding the sharp edges of the cardholder and the roughness left by the support residue.

Table 1. Responses from user testing.

User	Question 1	Question 2	Question 3	Question 4	Question 5
1	5	3 – Card bumps into camera bumper	5	4	Liked color, rounded features, and that case is only secured at the corners for minimalist design.
2	2 – Very slippery	3 – Card bumps into camera bumper	5	3 – Blamed ink as the problem, not the case	Liked “X” cardholder design, thought it was unique. Disliked that phone was only secured at corners, feels insecure.
3	3 – Slippery	4 – Card bumps into camera bumper	5	5	Liked stamp idea. Disliked feeling of sharp supports and sharp edges on the cardholder when holding phone.
4	3 – Smooth, not very grippy	3 – Card bumps into camera bumper	4 – ink can be messy	4 – Small features lost	Liked button cutouts. Disliked roughness of supports.
5	3	4 – Card bumps into camera bumper	4 – hard to tell if applied evenly	3	Liked corner bumpers, camera bumper, and button cutouts. Disliked “X” design (called it weird) and sharp edges on cardholder.
Avg	3.2	3.4	4.6	3.8	

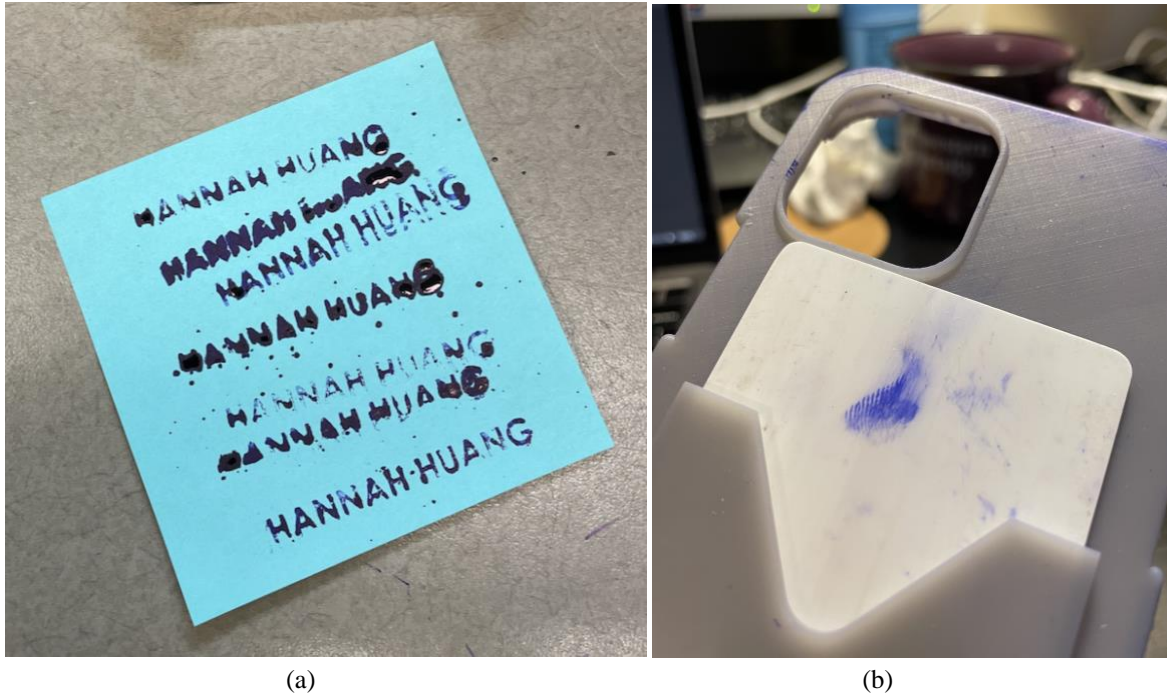


Figure 5. Images from user testing including (a) stamping outcomes of the phone and (b) card bumping into the camera bumper when removing the card.

For iteration 3, I used the same material but increased the layer thickness to 0.1mm because all the previous prints seemed to do well with 0.05mm, and I was curious to see if this would affect much. It would mean cutting down the print time in half. To address the slipperiness of the case without changing the material, I added ridges to the side of the phone for better grip. To fix the camera bumper problem, I considered a couple options. First, I could increase the thickness of the case to cover the camera lens without a bumper. Second, I could put the cardholder on an elevated surface. However, both of these options meant increasing the overall thickness of the phone case, which would lead to it being more bulky. Instead, I decided to add a small ramp to the bottom of the camera bumper that would allow the card to glide out and not run into the bumper. To improve the stamp quality, I decided to slightly increase the height of the stamp. Because of the functionality of the “X” design for taking out cards, I decided to keep it despite the conflicting responses. However, I decided to fillet all the corners and edges this time, so that it would be much more comfortable to interact with. I also made the “X” slightly skinnier so that it would be easier for users to drag cards out the top of the X if they choose to do that instead of pushing it out of the bottom. I also decided to keep only the corners folded over because it already fit very well, and I was worried that a totally enclosed design would make it very difficult to remove the phone from the case. For the final case, I also sanded down the supports, which I neglected to do on previous iterations. The final case is shown in Figure 6. While all the implemented changes worked out well, notice that the supports left a lot of residue on one of the grips (see Figure 6d).



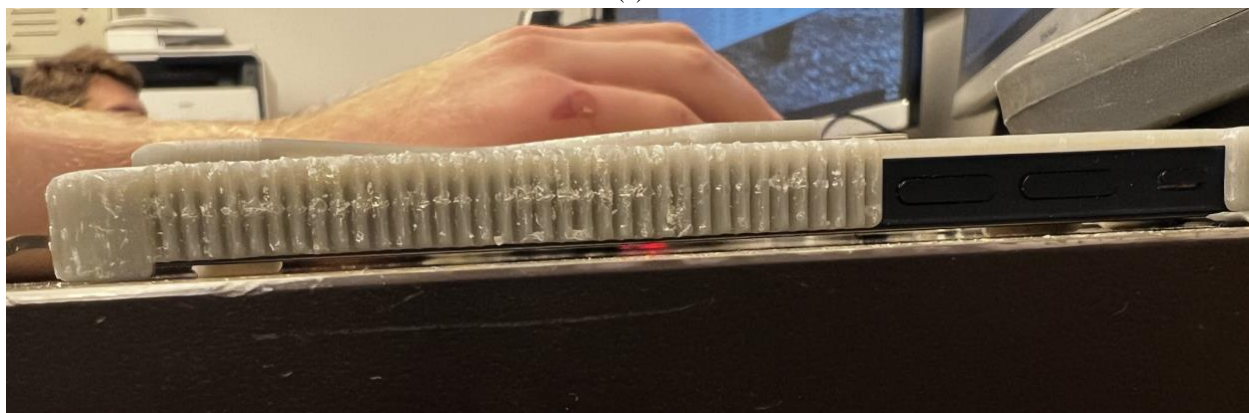
(a)



(b)



(c)



(d)

Figure 6. Final case showing the (a) front and (b) back, (c) stamp, and (d) verifying that the phone screen does not touch the table.

4. Conclusion

There were a couple difficulties I encountered with the 3D printing process. First, even with the model, getting the exact fit on the phone was difficult. After the first print, I took measurements of the clearances and adjusted my second iteration according. Also, I actually attempted to print my third iteration twice. The first time I printed it, the base lifted off the build plate, and the entire model was distorted. I also found that all the dimensions were smaller; the cardholder was too narrow to fit a card into. Because of the cardholder design, I was very limited in how I could orient this model as to not allow for unsupported minima. Thus, I decided to re-clean the build plate with alcohol and print on the same settings—it came out fine the second time. Finally, I underestimated how much time post-processing takes. After initial printing, I had to put it in an IPA bath for 15 minutes, then in a curing station for at least an hour. This is a lot different from a traditional desktop FDM printer, where the print can be taken right off the printer and used immediately after support removal. Support removal also took much more time, and they had to be removed very carefully because SLA produces very rigid supports (see Figure 7). For the final iteration, supports were made on the grips which turned the support-removal process into a one-hour ordeal.

However, this project was still much easier to carry out with 3D printing. I was able to model more freely because I did not have tooling constraints. And because there were open source models of my phone online, getting the fit was not too difficult. I was also able to design and print a new case in a relatively short period of time (within a day), which would not be possible with CNCing or injection molding, where I would have to write a whole new CAM between iterations or create an entirely new mold.

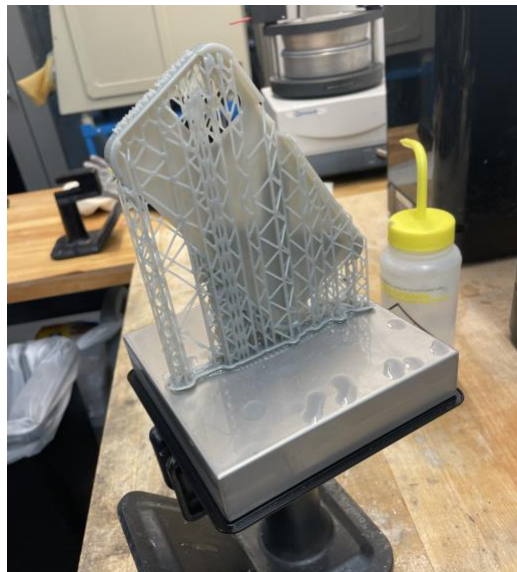


Figure 7. Supports on the final iteration.