**Senior Design Project: Cupcycle**

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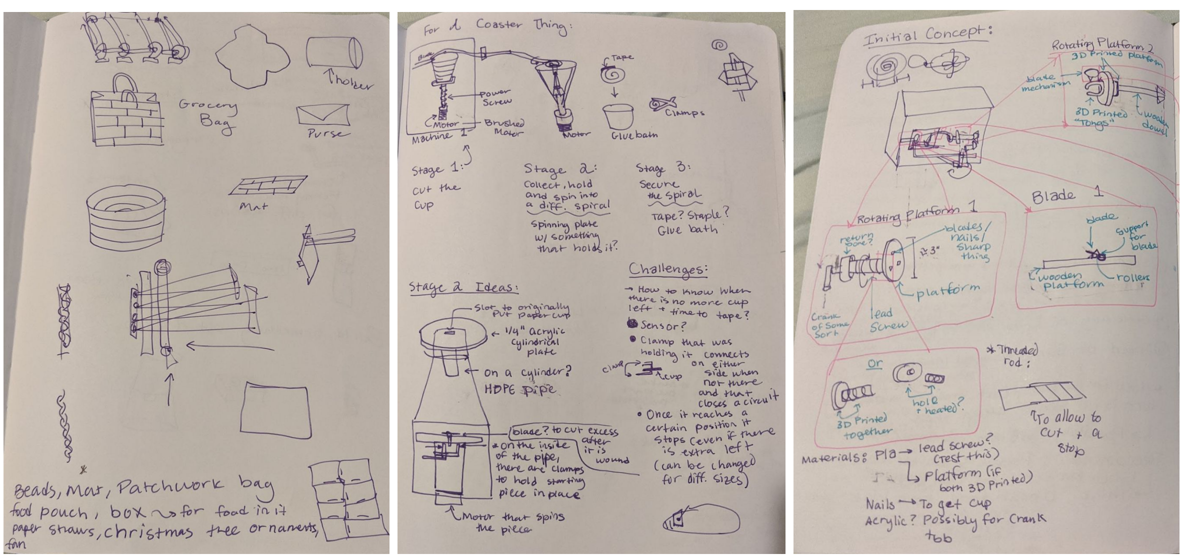
## Introduction

Currently, very few kinds of paper coffee cups can be recycled. Thin layers of plastic or wax prevent water from seeping through the cup but make it impractical to reclaim the paper for future use. While some coffee shops have adopted compostable cups, this practice is not yet widespread. Paper cups can be a major source of waste, which motivated us to find ways of repurposing (or, "up-cycling") the cups. We settled on designing a machine that could transform paper coffee cups into another useful product.

## Design Process

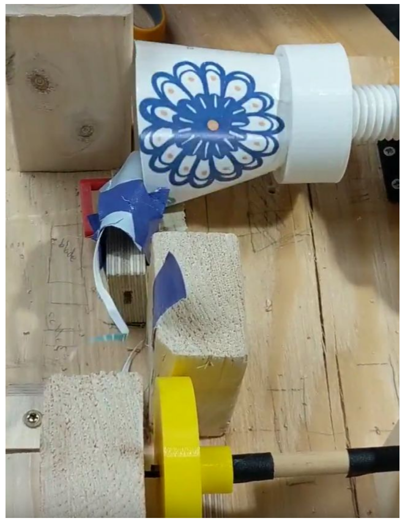
Rather than making something that would rely heavily on coding and electronics, we decided to create a purely mechanical design with a crank somewhat reminiscent of a penny-pressing machine. Ideally, the user would place a used paper coffee cup into the machine, turn a crank handle, and produce an entirely new product without adding any other materials. Coffee shops could implement this machine to reduce their cup waste and potentially generate more business through the novelty aspect of the machine.

Originally, we thought of creating woven bags or mats from long strips of different cups. The curve of the cup, however, made the strips difficult to weave and would require a separate material for adhesion. After brainstorming different options, we eventually focused our project on creating a machine that would create one long strip from a paper coffee cup and spin the strip into a spiral coaster.



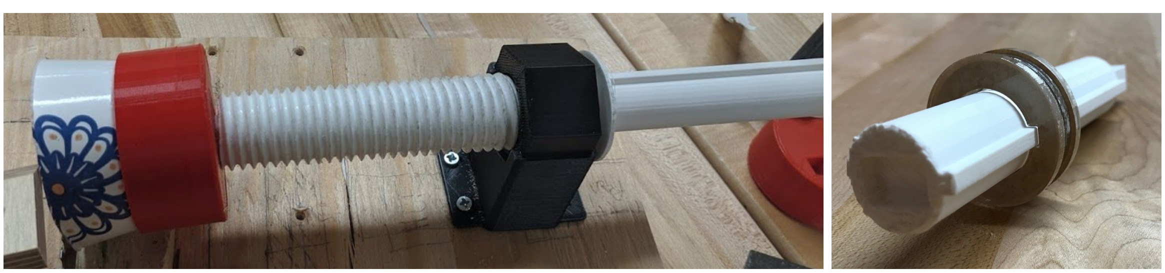

*Ideation Sketches*

Initially, we planned to mount the cup to a power screw that would be driven by a hand crank, similar in design to manual apple peelers. The cup would be sliced into a long strip by a fixed blade. The second stage of the machine would wind the strip around itself, creating a coil that could be used as a coaster. To keep the coil from unwinding, a heating element would press down on the strip, causing the thin polyethylene coating to adhere to itself. This heat sealing method is used during the cup manufacturing process to form the seam and attach the base.



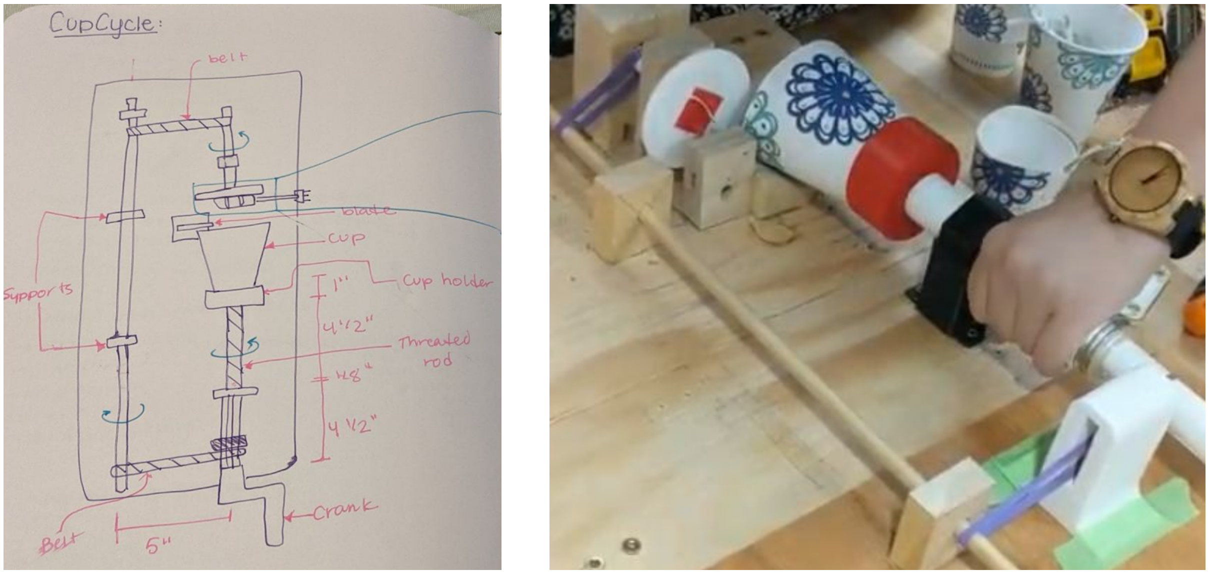
*Cutting and Coiling Stages*

We wanted both the cutting and the coiling processes to be driven by the same crank in order to make the machine easier to use. This posed a problem: the first shaft (used for cutting the cup) needed to both rotate and translate. Meanwhile, the second shaft had to only rotate. After some research, we decided that a spline coupling would be the best option. We added a longer shaft with one "tooth" onto the preexisting screw to which the cup was attached. Around this, we planned to use a gear or pulley with a keyhole shape cut out of the center to match the shape of the shaft. The gear or pulley and corresponding belt would be used to drive the motion of the cup coiling shaft. In this way, we would be able to accomodate the simultaneous rotation and translation of the cup as it was being cut while also enabling the strip coiler to only rotate, and everything would be powered by the same crank.



*Power Screw with Keyhole Coupling*

While we prototyped with the power screw design, we discovered several problems. We had planned to mount several prongs to the second shaft so that the strip would pass between the prongs and coil over on itself. However, the strip that we were cutting was flimsy and moved unpredictably, making it difficult to feed between the prongs. We overcame this issue by placing the second shaft immediately next to the blade, leaving little opportunity for the strip to miss the prongs.

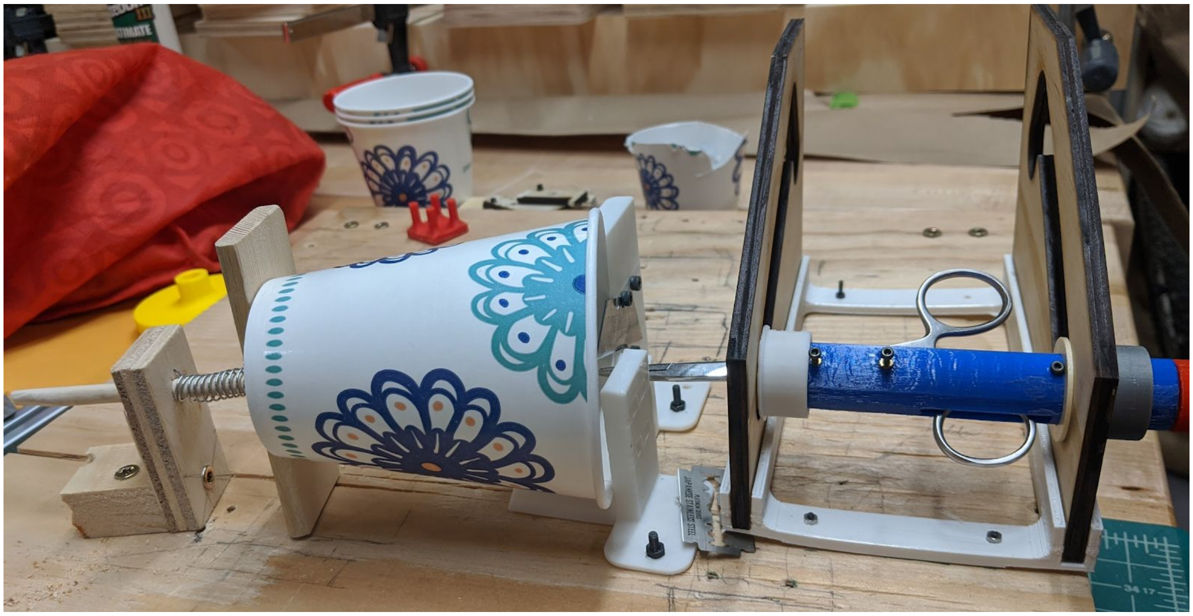



*Adjacent Shaft Design*

After we solved that issue, however, it became apparent that there was a bigger problem with our design: as the coaster grew in diameter, longer and longer sections of the strip were needed for every rotation of the coil shaft. In other words, the strip was cut at a constant rate but wound at an increasing rate. We decided that the non-linearity of the two shafts would be too difficult to resolve with our current design and instead focused on a new approach.

Rather than "push" the cup through the blade with a power screw, we decided to attach the cup to a fixed point and then pull it through the blade. Once the cutting began, the strip would then be wound around the fixed point to form the coaster. This strategy would resolve the nonlinear issue, since the cutting and the coiling would both be driven by the same motion. As an added bonus, the strip would always be constrained, and would not need to be fed between prongs for coiling.

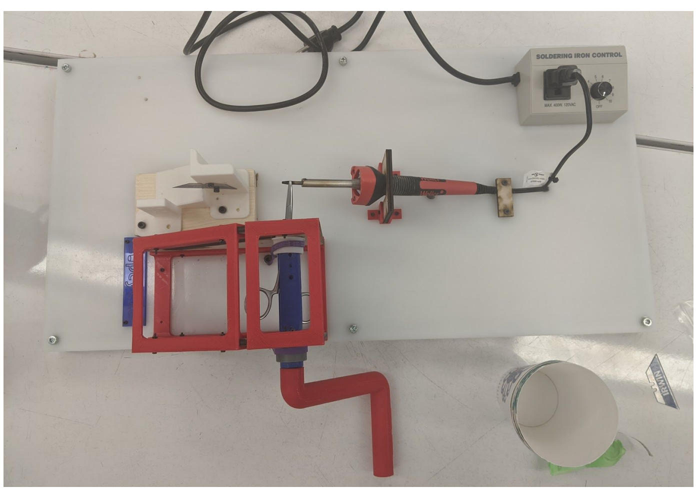
To accomplish this, we decided to clamp the brim of the cup, slide the cup through the blade, and then spin the clamping mechanism to complete the process. We chose forceps to clamp the cup because they could be locked into place and released with relative ease. In addition, they are fairly small and therefore easy to rotate axially. The forceps were mounted to a 3D-printed shaft connected to a crank. The shaft rested on laser-cut rails to allow translation for the initial cutting step. Throughout the spinning step, we aimed to apply a heating element to the outside of the coaster to seal the strip in place. We decided to mount a soldering iron to the machine base and spring-load it to constantly provide an upward force on the coaster.



*New Design*

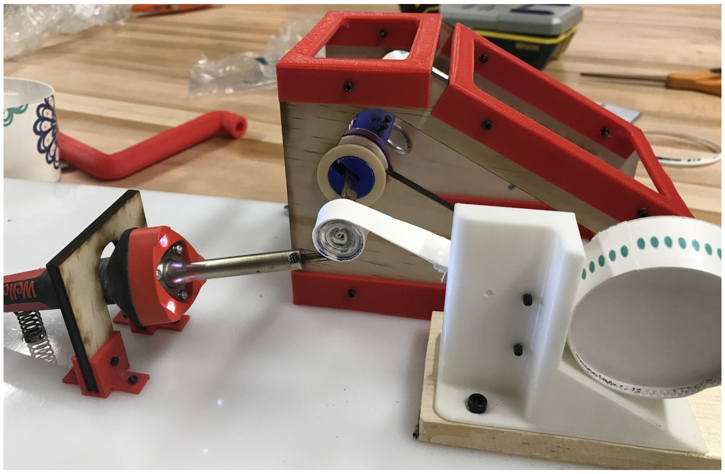
**Final Design**

In our final design, the user places the cup in place and clamps the forceps onto the edge of the cup. They then slide the crank assembly on a set of rails, which drags the cup through the blade and cuts it into a thin strip. The crank assembly locks in place at the end of the rails, allowing the user to turn the crank to continue cutting the cup. As the crank turns, the strip coils around itself and presses against a spring-loaded soldering iron. The iron seals the strip to prevent uncoiling. Once the cup is completely cut, the user releases the forceps and slides the coiled coaster off of the crank mechanism.




*Final Prototype*

*Completed Coaster*



*Coiling and Heating*

**Conclusion**

While working on this project, we learned a great deal about mechanisms for conveying different kinds of motion. In our initial approach, we needed to drive two shafts using one crank. The first shaft needed to translate and rotate to cut the cup, but the second shaft needed to only rotate to wind up the coaster. In addition, we gained an appreciation for the difficulty of working with non-linear systems. We achieved very consistent cutting when the cup was driven through the blade on the power screw, but this unfortunately required a varying speed for the coiling of the coaster. As a compromise, we altered our approach so that the cup was pulled through the blade with the forceps; this strategy avoided the issue of non-linearity but was significantly less effective at cutting.

The flexible nature of the cup posed many problems while we were testing and refining our ideas. One thing that we realized was that constraints on the cup and strip were crucial to having the machine operate as expected. When we first experimented with cutting the cup, we noticed that the cup buckled very easily when it was unsupported. We also discovered that after the strip was cut, it tended to travel on an unpredictable path. The solution to these issues was to constrain the cup and strip so that their motion would be fully controlled.

**Future Work**

Although our design was functional by the end of the work period for this project, there are several improvements we could make if we had more time and resources. First, the forceps we used to clamp onto the cup were somewhat finicky and often released their grip at inopportune times. In addition, because of the very small contact area of the forceps on the cup, the cup would sometimes rip near to where the forceps were. These issues could be resolved by having a larger surface area to clamp onto the strip of cup.

Additionally, while working on this project, we ran into numerous issues with the blade we were using to cut the cup. We purchased and tested a wide variety of different blades, but none of them worked quite as well as we would have liked. As a result, when cutting the cup, more force had to be used than we would have liked, and when trying to cut through the seam along the side of the cup where there were two layers of cup material rather than just one, the blade was sometimes unable to cut at all, and the thin strip of already-cut cup would rip instead.

To solve this issue in the future, we could perform more in-depth research on different types of blades and test many more blades ourselves to determine the best option to use for this application.

Finally, the coasters we were able to make were very thick and had smaller diameters than desired. To solve this, we would have to cut the cup into a significantly thinner strip. This would make the coaster thinner while also enabling more cup material to be used towards making the coaster have a larger diameter so a glass or mug would actually be able to fit on it.