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ME153 - Introduction to Mechanical Engineering Design

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Final Report: Robust Resin Filtering Station for 3D Printer Maintenance

<u>I) Design Process</u>

1) Introduction:

a. Problem Definition: SLA 3D printers work by selectively curing liquid resin using a UV laser. They use a resin tank to hold the material during polymerization. The tank needs to be cleaned to change materials or recover failed prints; this process requires filtering the existing resin out of the tank. This process is difficult due to the high viscosity of the resin.

b. Target Users: Enthusiasts and makers who use SLA 3D printing face this problem.

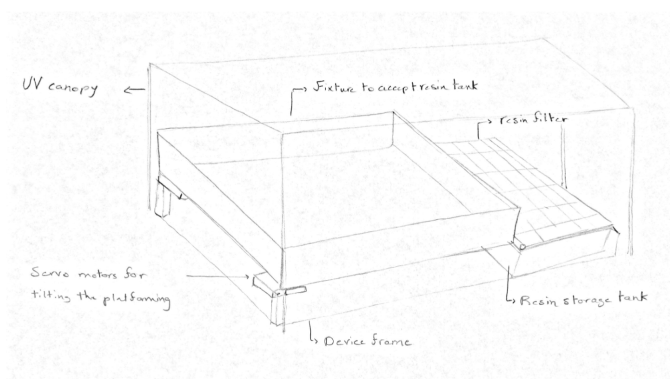


Figure 1: First concept sketch for filtering station.

c. Proposed Solution: An automated filtering station, featuring a rotating tank fixture actuated by a motor, accomplishes this time-consuming task and frees up the user to do more meaningful work.

2) Prototype 1:

a. Ideate: This prototype aimed to understand how many degrees of freedom was needed to pour resin reliably. A cardboard model was made to examine the use of one actuated hinge, one actuated hinge at a fixed tilt (along a second axis), and two actuated hinges.

b. Prototype and Test: Testing suggested that one actuated hinge was inadequate for pouring in a repeatable fashion, but one actuated hinge at a fixed tilt proved to be a successful method for pouring viscous liquids.

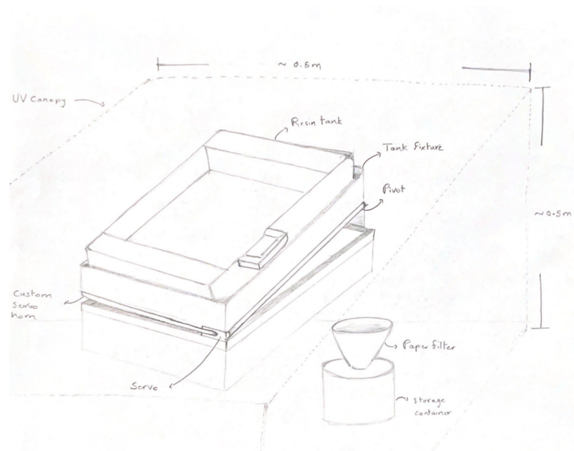


Figure 2: First prototype examined reliable pouring.

c. Analyze: Based on testing results, it was determined that the station would use a single actuated hinge at a fixed tilt.

$$\tau_{motor} - mg\frac{l}{2} = I\alpha$$

$$\tau_{motor} = 0.0332\ kg\,m^2(0.1\ rad/s^2) + 1.10\ kg(9.81\ m/s^2)\left(\frac{0.290m}{2}\right)$$

$$\tau_{motor} = 1.57\ N{\cdot}m.$$

~1.57 N·m torque required.

3) Prototype 2:

a. Ideate: The second prototype integrated a servo to the cardboard model. This was accompanied by planning for the fabrication of the frame

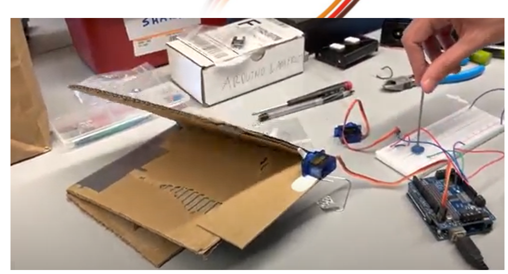


Figure 3: The second prototype focused on motor integration and torque analysis.

using extruded aluminum bars, and torque requirement analysis.

b. Prototype and Test: The prototype pinned a servo to the cardboard model to demonstrate control over the pouring regime. The engineering analysis guided motor selection and the device's dimensions.

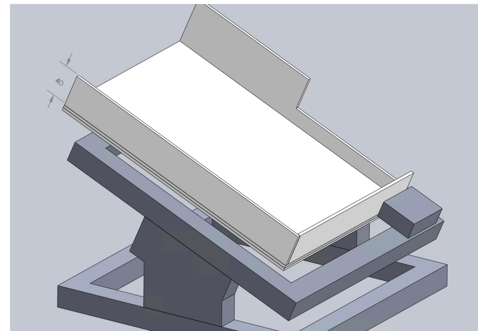
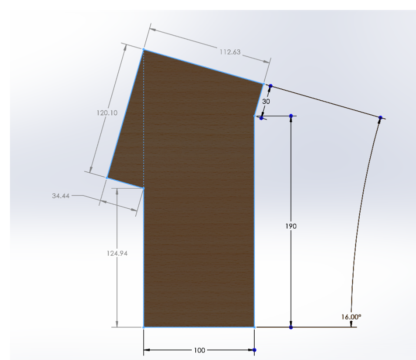


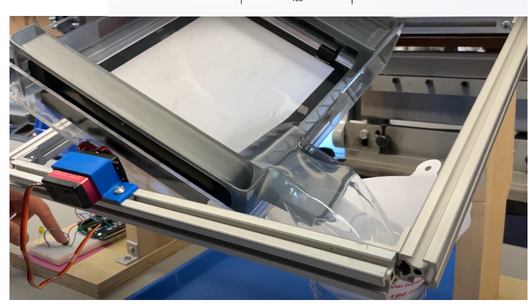
Figure 4: The third prototype integrated the motor with a frame.

c. Analyze: The motor torque needed for the longest possible arm was evaluated to be 1.6Nm; a motor capable of supplying 2.5Nm was ordered and the lever arm was shortened by moving the servo to the center of the frame. Furthermore, difficulty in synchronization of servos led to the use of a single servo for future prototypes.

4) Prototype 3:

a. Ideate: The third prototype integrates the servo motor with an aluminum frame and a custom acrylic fixture.





b. Prototype and Test: The prototype was assembled using 3D printing, laser cutting, and manual machining processes. Preliminary testing highlighted the device's ability to move as expected.

Figure 5: The fourth prototype emphasized improved fabrication.

c. Analyze: While this prototype was a successful proof of concept prototype, it demonstrated necessary adjustments to the dimensions of the frame and the fixture to accommodate the resin tank and the filter along with improvements to the pivot pin.

5) Prototype 4:

a. Ideate: This prototype focused on re-designing and fabricating the frame with elevating wooden wedges that enabled the accommodation of the resin filter.
b. Prototype and Test: The frame was made out of wood, and testing was carried out with thick water to replicate the resin. During testing, an incremental pouring regime was implemented to progressively tilt the resin tank in five steps to allow well-controlled pouring.

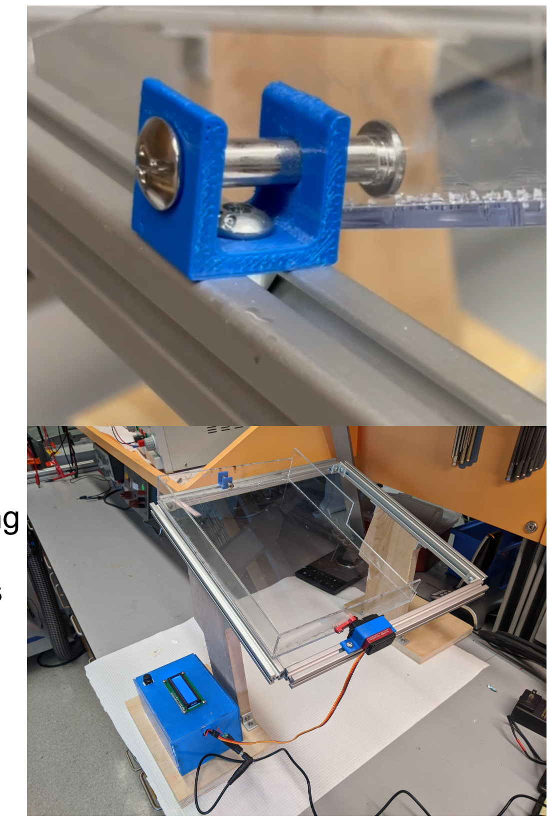


Figure 6: The fifth prototype made final refinements to the operating system.

c. Analyze: Despite the success of the prototype, this prototype highlighted the need for redimensioning of the wooden wedges and the use of a binding barrel as the pivot pin. The next step would be to implement an electronics enclosure.

6) Prototype 5:

a. Ideate: This prototype aimed to carry on all of the improvements from the previous prototypes while adding an electronics enclosure and user interface.

b. Prototype and Test: The electronics enclosure was cut from acrylic sheets. An LCD was used to show the status of the machine, and a button was used to initiate or terminate the pouring cycle.

c. Analyze: Testing with thick water showed the device performed reliably.

7) Prototype 6:

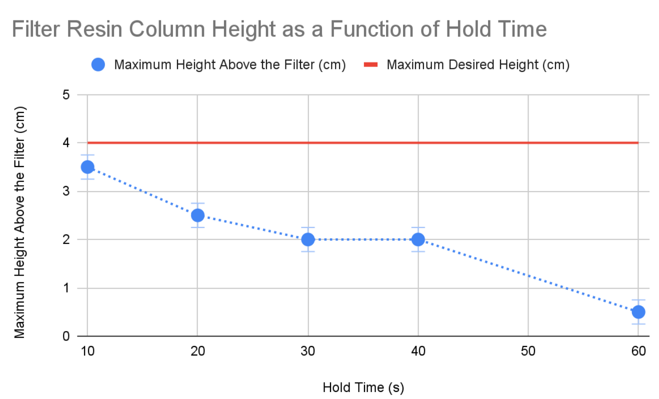


Figure 7: Results from characterization experiments.

a. Ideate: The objective of the final prototype was to determine an automated pouring routine that would accommodate the Flexible V2 Resin (Formlabs, Somerville, Ma).

b. Prototype and Test: The figure of merit used in testing was the amount of resin accumulated in the filter paper. The objective was to maximize this height to drive the filter as fast as possible while keeping the filter in operational conditions and avoiding overflow. The hold time between each pouring step was altered and the column height was recorded for each experiment.

c. Analyze: The results indicate that a hold time of 10 seconds per step achieves rapid pouring and filtering without overflowing the filter paper. This figure was subsequently implemented for use in the device.

II) Reflections:

1. **What surprised you about the design process, about your team's product?** The time involved in procuring parts limited the progress far more than we expected, as we often found ourselves waiting on parts before we could continue prototyping.

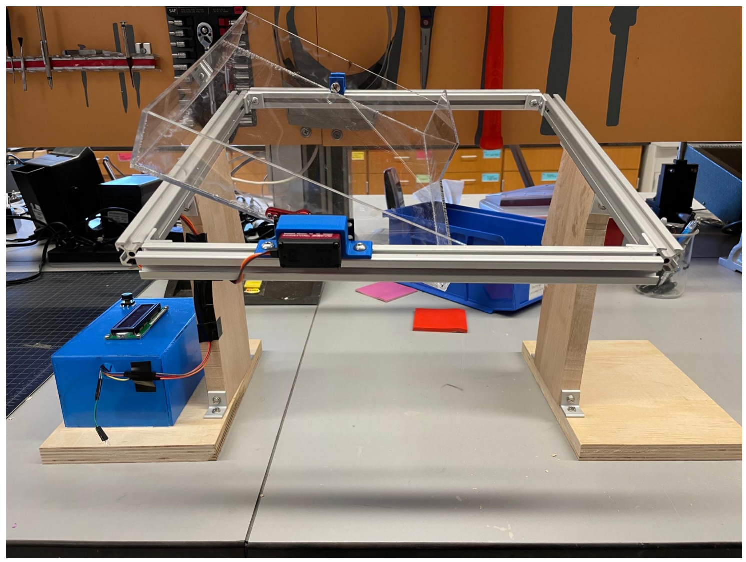


Figure 8: Image of the final prototype after testing.

2. **Where did you fail, where did you succeed?** Our greatest success was in being conservative when setting initial objectives; our main failure was that we lacked more novel solutions to problems like residual resin on the tank that has to be scraped off by the user, or a design that would protect the motor from a longitudinal load if anything fell on the acrylic bed.

3. **On reflection, do you feel that your prototype shows that your design has promise? – is it worth developing further?** The design can be worthwhile and is functional. We think that if the design could be made more compact and cost-efficient, it

could be useful in printing hubs that use several printers and frequently need to filter resin.

4. **What changes would you make in the next iteration?** Adding feedback control, minimizing the footprint of the design, and creating a UV canopy that could prevent the resin from curing prematurely could all be worthwhile additions.

5. **You will work on another design team in Capstone next year. Would you organize your team's work any differently looking back on this quarter's work?** Our work distribution was well thought out for this quarter - we would continue with the same approach while emphasizing a clear definition of responsibilities.