ToastBot

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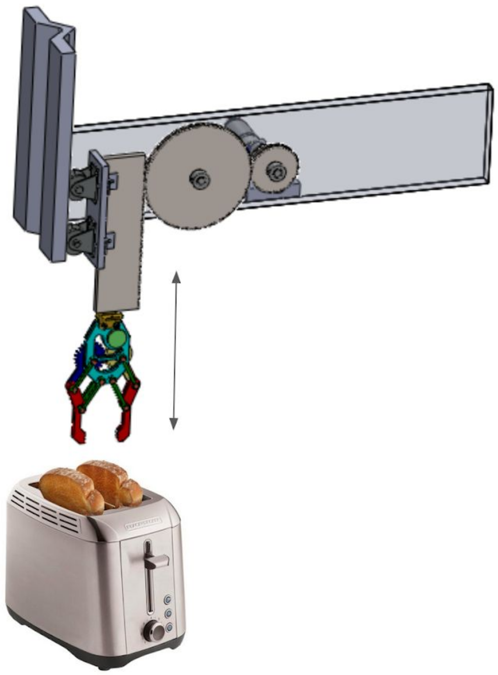


Product Description:

Have you or a loved one ever burned your fingers when making toast? Look no further, ToastBot is here. ToastBot solves the age old problem of burning your fingers from grabbing toast right out of the toaster. ToastBot grabs toast from the toaster for the operator to prevent any fingertip discomfort. Figure 1 shows a sketch of ToastBot. A standard operating procedure is: Toast comes out of the toaster which pushes a button to activate ToastBot → ToastBot's prismatic joint moves down to reach the toast → A gripper on the end of the arm grabs the toast → The prismatic joint moves back up to lift the toast from the toaster → ToastBot rotates to present the toast to the operator → The gripper opens and the toast is dropped (hopefully) onto a plate.

Because of the time constraints of this project I was unfortunately not able to design all of ToastBot. So, for my final project I focused on the prismatic joint and all of the mechanical components that go into making it functional. Please note that the gripper in the CAD is mainly just for show and has not been fully integrated into the design.

When designing this product I wanted it to be something that I could actually build as a student. Therefore I chose fabrication methods that are accessible to me (at least during a regular semester) and to minimize cost. These decisions will be further discussed later on in the report.

Parts List:

Part	*Quantity*	*Vendor*	*Price*
¼'' plywood 18'' x 30''	1	Jacob's Hall	$4.70
½'' plywood 2'' x 4''	1	Home Depot	$16.07
Pololu 25:1 Metal Gearmotor 20Dx41L mm 6V CB with Extended Motor Shaft	1	Pololu	$22.95
8mm diameter keyed rotary shaft (300mm length)	1	McMaster	$21.85
Flanged shielded ball bearing 8mm x 12 mm	6	McMaster	$11.29 each
Shims 8mm x 10mm (25 pack)	1	Amazon	$12.85
Motor metal bracket	1	Pololu	$6.95
Flexible shaft coupling	1	McMaster	$11.92
Shaft collar	10	McMaster	$1.91 each

Belville (spring) washers pack of 12	6	McMaster	$3.92
Aluminum track 5’’ long	1	Fencesngates	$18.95
V groove track rollers pack of 4	1	Amazon	$21.99
Steel M3 hex nuts pack of 100	1	McMaster	$0.88
Hex drive button head M3 screws pack of 100	1	McMaster	$3.54
Zinc plated steel corner bracket	4	McMaster	$0.68 each

Design:
In this section I will elaborate on each of the major components in the design.

Gear Train:

The gear train is necessary in ToastBot to increase the torque of the motor such that the toast can easily be lifted with the gripper.

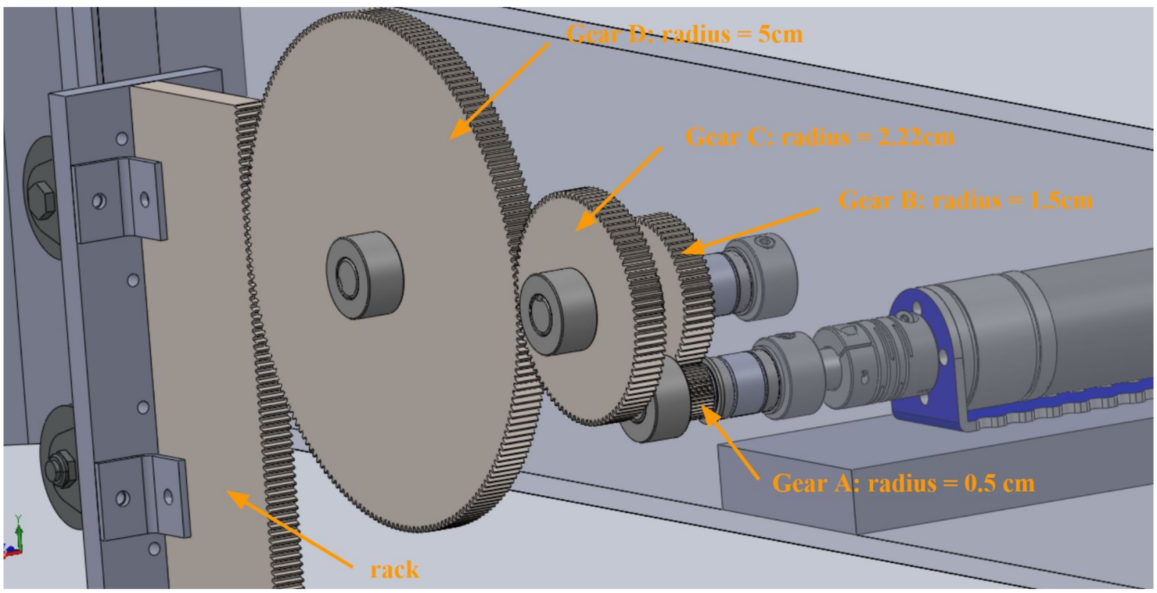


Figure 2: Gear train assembly with dimensions.

Calculating gear size: In order to calculate the required torque of the gear train the final gear (gear D) was modeled as a pulley that needs to lift 2.5lb = 1.1kg. While an average piece of toast is nowhere near 2.5lb, I wanted to be sure that the motor could easily lift the toast, the rack, the gripper, and any other associated hardware.

I chose the largest gear to have a 5 cm radius. From there we can calculate the required torque to be 0.54 N-m.

$$\tau = (1.1\ kg) * (9.81\ m/s^2) * (0.05\ m) = 0.54\ N \cdot m$$

In my apartment I had a Pololu 25:1 Metal Gearmotor 20D from a previous project, so I decided to use that motor for ToastBot. This motor has a listed stall torque of 1.6 kg-cm = 0.16 N-m. To remain in a safe operating range we will assume that the output of the motor is half of the stall torque (0.08 N-m) . From here we can calculate the required gear ratio:

$$R_{overall} = \frac{\tau_{output}}{\tau_{motor}} = \frac{0.54\ N\cdot m}{0.08\ N\cdot m} = 6.75$$

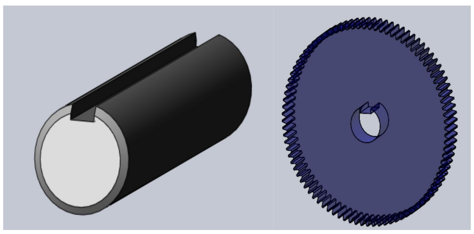
Because the required gear ratio is greater than 5 we will need two gear-to-gear interactions (4 gears). This is a precaution to prevent teeth from shearing off. We can then decide the intermediate gear ratios that we will use to get to an overall gear ratio of 6.75. I chose to have $R_{AB} = 3$ and $R_{CD} = 2.25$. From there I found the radius of gear C:

$$R_{CD} = \frac{r_D}{r_C} = \frac{5\ cm}{r_C} = 2.25 \quad \rightarrow \quad r_C = 2.22\text{cm}$$

I then chose values for r_A and r_B based on the gear ratio R_{AB}:

$$R_{AB} = \frac{r_B}{r_A} = 3 \quad \rightarrow \quad r_A = 0.5\text{cm},\ r_B = 1.5\text{cm}$$

Now we have defined the dimensions for all of our gears. Figure 2 shows the final gear train.



Other Considerations: I chose a module of 0.5 for all of the gears. The gears are keyed such that they can lock into the keyed shaft as shown in figure 3. This will aid with fixturing beyond just adhesive.

Assembly: Gears and the rack needs to be laser cut out of ¼'' plywood. Glue should be applied to the gears before they are secured onto the shaft. Assembly onto the shaft will be further discussed in the next section.

Transmission:

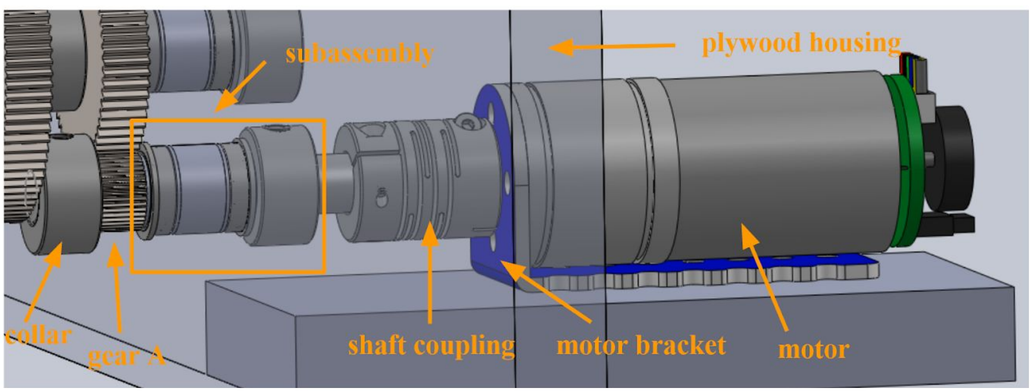
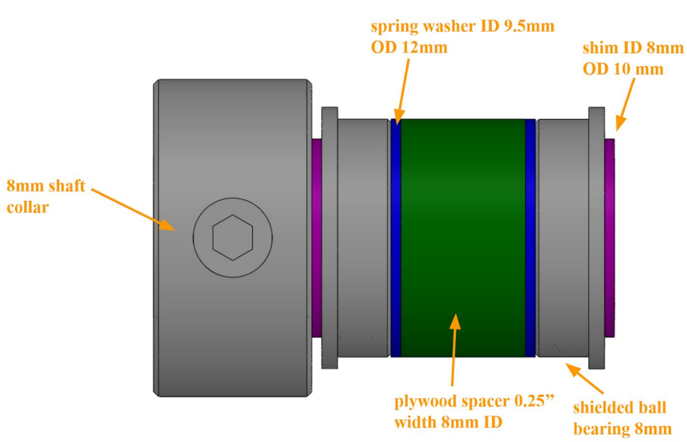


Figure 4: Transmission assembly. Figure 5 shows the bearing sub assembly in more detail.

Considerations: The transmission is built in a similar way to what was discussed in the course. Figure 4 shows the overall assembly.

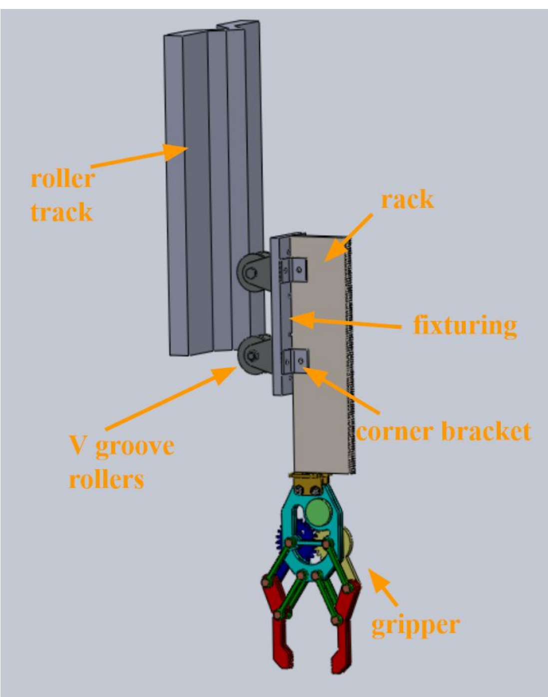
The ¼'' plywood spacer is used such that the bearings can be preloaded using the Belville washer. This way the washer only comes into contact with the outer race of the bearing. Figure 5 shows more detail of the bearing subassembly in figure 4. In the other shaft assemblies collars are used as spacers instead of just using ring shims. This was done because the cost of ring shims and collars is comparable for such a small project. This is because ring shims are usually sold in bulk and this setup requires an odd size.



Assembly: First we need to laser cut the ½'' plywood using the CAD design such that the bearings and shafts can be secured into the wood housing. Then the shafts need to be cut to length. This can be done using an angle grinder. There is probably a more accurate way to do this but this is the tool I have previously used. From there the components need to be pressed onto the shaft in the order shown in the figure 4. Start with the collar closest to the gear and work down the shaft. Once you reach the first Belville washer, position the assembly into the wood housing. Insert the spacer, the other washer, and then the second bearing. Press the bearing into the wood housing. Place another shim and then secure the assembly using the other shaft collar. Make sure both shaft collars have been tightened effectively. Use M3 screws to secure the motor onto the motor bracket. Insert the shaft coupling onto the motor and the shaft. Tighten the set screws on the shaft coupling. The specifics of this protocol will vary slightly between shafts but the general method of the assembly can still be used.

<u>Prismatic Joint:</u>

Considerations: In order for the prismatic joint to be effective for this application it needs to provide low friction linear motion. I understand that using a linear slide would be the most robust and accurate way to provide this linear motion, however linear slides can be very expensive. In order to circumvent this I was inspired by sliding closet doors. I used V groove track rollers attached to the joint to provide low friction linear motion.



Assembly: First, the fixturing wood piece needs to be laser cut. This piece is used to connect the roller to the rack because the rack itself is too thin to connect to the rollers. The rollers can then be secured onto the fixturing wood piece using M3 screws and nuts. The rack can be connected using the right angle brackets and M3 screws and nuts as well. Holes need to be drilled and tapped into the roller track. This way the rail can be attached to the outside housing (this is not yet designed).

<u>Improvements for Next Iteration:</u>

The main issue with ToastBot is right now the product is somewhat over designed. In this project I really tried to use the skills learned in class, but some of them were probably unnecessary. For one the prismatic joint could just be something as simple as a lubricated slot if I did not want to use a linear slide. The rack is also not secured very well in the way I have it because it is relying on the pressure from gear D, however that could be fixed with the housing.

It also may be difficult to laser cut such fine gears. Right now the module is 0.5. It could be increased and result in the same behavior. The module could also be increased later on in the gear train. We could also probably get away with just two gears if slightly higher motor torque slightly lower load. The gear could also be placed in between the two bearings to put less force on the bearing by eliminating the cantilever.