5.5 Belt Tensioner

(Jennifer Lee)

5.5.1 Introduction

(Jennifer Lee)

Our current model improves upon the initial design with a custom-designed belt tensioner. Given the added complexities in the pulley/gear system, the belt tensioner maintains a constant amount of pressure on the engine belts. Figure 38 illustrates the belt tensioner, which is a pulley mounted on the spring mechanism that allows for automatic tension maintenance (spring tension adjusts to necessary tension within the belt). Depending on the necessary spring tension, the displacement of the drive belt pulley varies, which further varies the tension applied onto the belt (see figure 18 and 39).

Motor control is also improved in the system, both in accuracy and efficiency, with the added belt tensioner. In the previously designed system, there was a risk of possible skipping and jumping when all of the gears were in direct contact with each other. The belt tensioner is a necessary correction for this issue. When the belt tensioner pushes against the belt, it increases surface contact (see Figure 38).

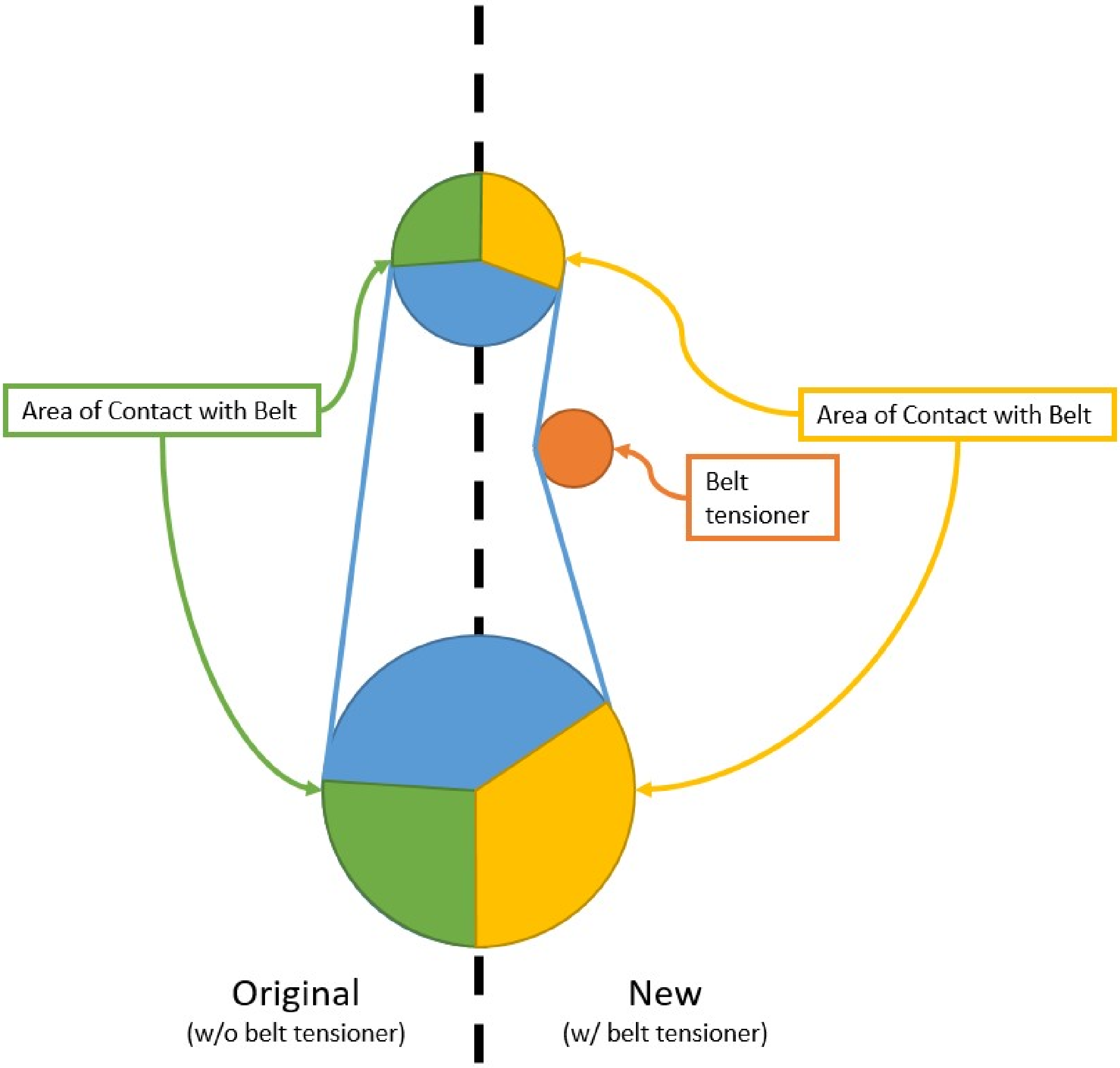

Figure 38: Graphic of belt tensioner's effect on belt tension and area of contact.

5.5.2 Calculations

(Jennifer Lee)

To establish initial constraints onto the belt tensioner, assumptions about the larger and smaller gear and the hull width had to be made. We used approximations of 1.33 in diameter for the smaller pulley and 3.25 in diameter for the larger pulley (See Figure 39). The distance between the two pulleys were measured to be around 4.3 in and the timing-L-belt had a width of about 0.75 in, allowing a z-axis margin of error of about 0.25 in within the gear.

From these approximations, the deflection of the belt and the tension necessary for the tensioning pulley was calculated using an online calculator. From this we approximated a necessary tension requirement of 11.3 in-lbs to 15.4 in-lbs for the spring (see Table 2 for input values).

Table 2: Tension Calculator Inputs: Timing Belt

Specification	Classical
Tooth profile	L
Belt width	19 mm
Number of teeth on large pulley	36
Number of teeth on small pulley	12
Revolution of small pulley	100 rpm
Center distance	127 mm

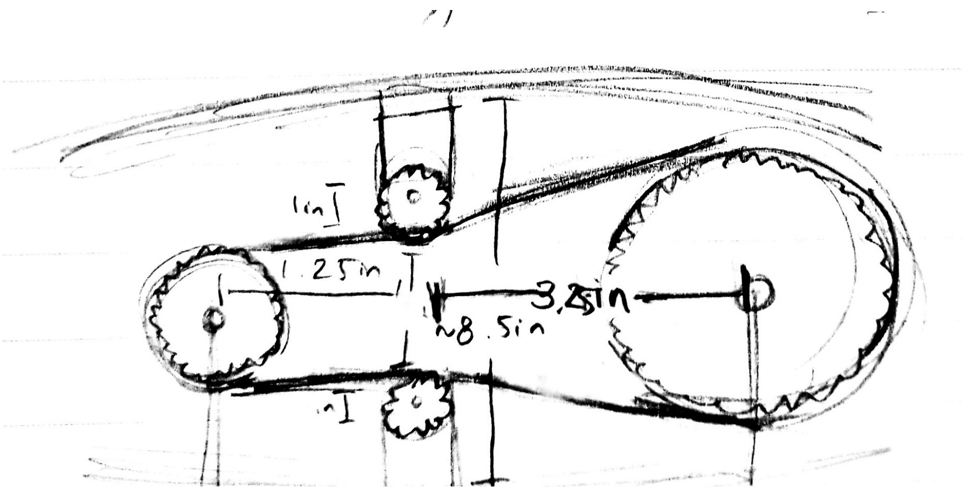

Figure 39: Motor control belt system measurement approximations from last semester.

5.5.3 Previous Iteration

(Jennifer Lee)

Last fall, to reduce the number of moving parts, the previous iteration expanded the hinge idea. The two options for the hinge idea was the decision to have the spring external or internal (see Figure 40). As seen in the figure, despite significant decrease in moving parts for the external spring, the external spring is insecure and exposed. It also increases the potential of the spring interfering with the moving belt of the motor control system. The internalized torsional springs of the figure shows smaller and more moving parts than the externalized spring, but it is significantly internalized and cleaner, allowing for easy adjustment and flexibility of individual parts. It also relies less on symmetry unlike the external spring system.

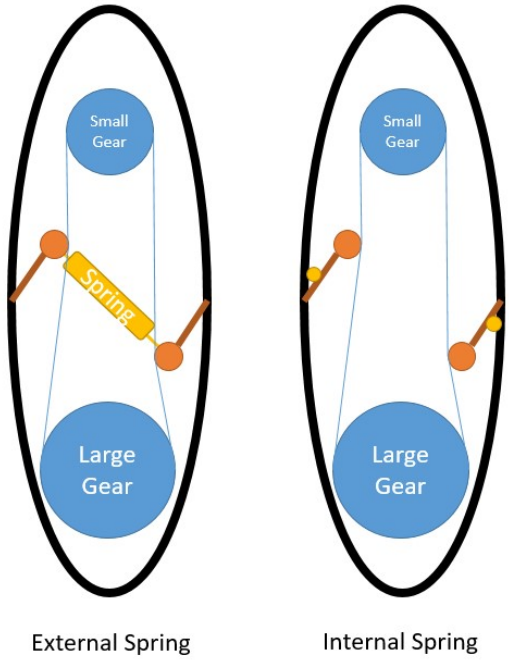

Figure 40: The basic externalized and internalized spring graphic. Orange is the belt tensioning gear system as the yellow represents the springs. The blue is the original motor control system (belt, small gear, large gear).

The previous iteration incorporated 3 separate parts: the tensioner base, the tensioner arm, and the screw-rod (see Figure 46 for general assembly). The tensioner base's purpose was to standardize and regulate the movement of the belt tensioner within 90 degrees and level to the x-axis. The tensioner arm held and attached to the gear itself with two ball bearings and 2 pins. The screw-rod is the rod that holds together the springs, the tensioner arm, and the tensioner base together, but allows concentric rotational movement.

Most of the manufacturing was done by 3D printing, but because the pieces were too small, the dimensions were inaccurate and rough (See Figure 41). Thus, depending on the purpose of each piece, the base was to be 3D printed, the tensioner arm was to be cut from acrylic, and the screw-rod was to be made with aluminum. When detailing the assembly of each of the pieces, there was to be inserted threads for the tensioner base so that it will be easily screwed onto the hull support frames; the support frame itself was to be epoxied onto the hull directly. This prevented any issues regarding waterproofing and damaging the hull of the boat.

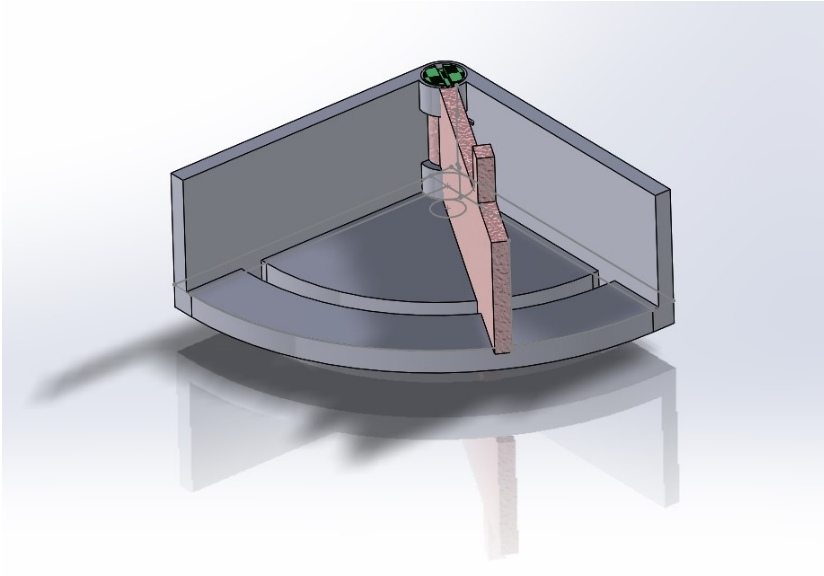

Figure 41: A rough CAD assembly of previous iteration

5.5.4 Re-engineered Design Goals

(Jennifer Lee)

Originally, the main goals for the belt tensioner included durability, flexibility, and efficiency. When considering flexibility, some considerations included part interchangeability, modifiability of each part, and adaptability of each part.

However, with a focus on flexibility, the durability of the device was highly sacrificed. When printing out the 3D parts, we found that it was easy to snap them even with the force of a gentle push. This was highly disconcerting. The pieces were also very small this meant that assembling was highly difficult and we even worried that the design would not be able to support the weight of the servo gears themselves (See Figure 42).

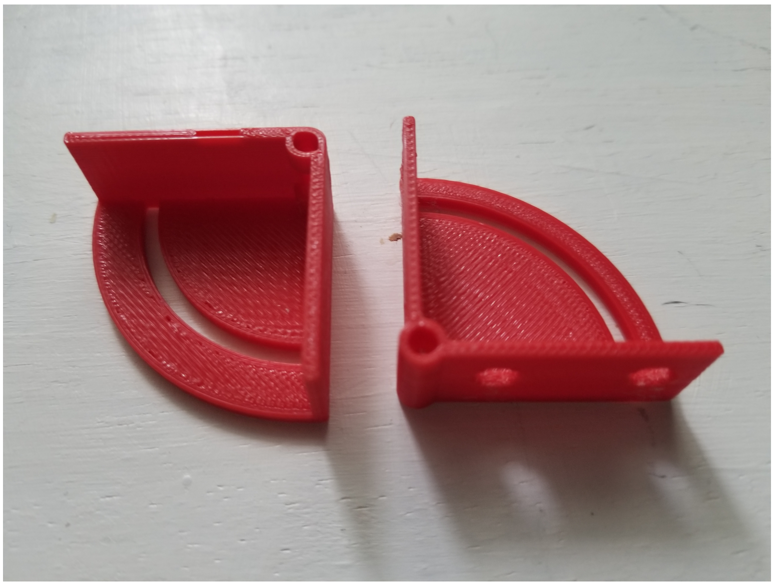

Figure 42: 3D-printed previous iteration

From this, the finalized design's main objectives were high durability and easy manufacturability. With these goals, this meant that the pieces would have to be metal and the construction had to be much simpler.

5.5.5 Finalized Iteration

(Jennifer Lee)

This design focused on the manufacturability/machinability of the belt tensioner. Although we used the same principles as the previous iteration, we found that simplifying each of the components was the easiest way to increase durability. By simplifying, the design could potentially avoid fragile parts, 3D printing, and difficult machining.

For the final iteration, the belt tensioner hull support was kept so that direct attachment to the hull is avoided. The torsional springs and gear were kept as well.. However, to increase durability and reliability, skate bearings and an aluminum arm were added. Figures show the sketches initiating the final iteration.

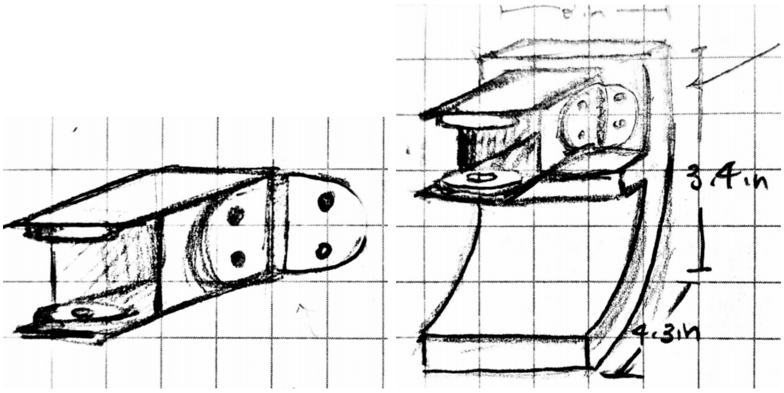

Figure 43: Rough CAD of what final assembly of belt tensioner should look like.

Figure 44 and Figure 45 demonstrates the final assembly of each of the components. Table 3 includes all purchasable parts with links. Some things that changed within the final CAD include the location of the hinge which from the outside of the rectangular aluminum piece to the inside and the removal of the supportive base which reduces any unnecessary weight and friction against the aluminum piece.

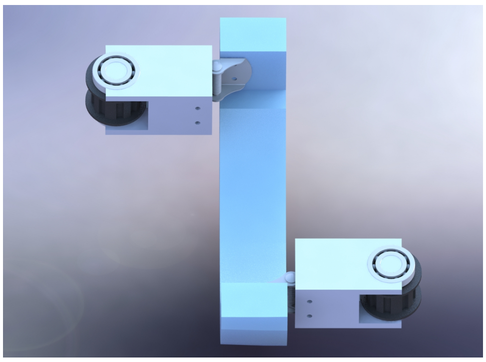

Figure 44: Rough CAD of what final assembly of belt tensioner should look like.

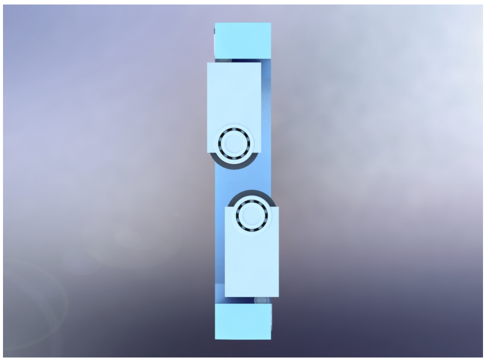

Figure 45: Rough CAD of what the hinges folded should look like.

Table 3: Table of Purchased Parts

Material	ID number	Quantity	Total Cost	Machined
Aluminum Rectangular Tube	6546K23	1/2 foot	$9.52	Yes, cut
Surface-Mount Spring Hinge	1613A11	2	$3.92	No
Plastic Timing Pulley	A6Z4-10 DF07512	2	$22.72	Yes, cut and drilled
Ball Bearing	60355K505	4	$25.08	No
Aluminum Rod	8974K28	1/2 foot	$1.70	Yes, cut

A hollow rectangular piece reduces weight, increases machinability, and strengthens the structure. The chosen self-closing hinge is modular so the spring within is easily replaceable and the hinge mechanism is ready made so it reduces the manufacturing process (See Figure 46). Skate bearings replace the sketch's thrust bearings to reduce the thickness of the hollow rectangular aluminum stock and to have a more reliable structure for the gear to spin on.

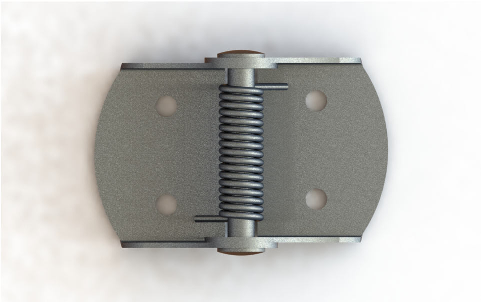

Figure 46: Modular self-closing hinge.

5.5.6 Manufacturing Plan

(Jennifer Lee)

First, the support hull would be 3D printed (See Figure 47). Although 3D printing could be avoided by CNC-ing the part out of aluminum, 3D printing is more suitable. This allows easy adjusting, reproducing, and machining.The support hull would be epoxied onto the boat's hull directly.

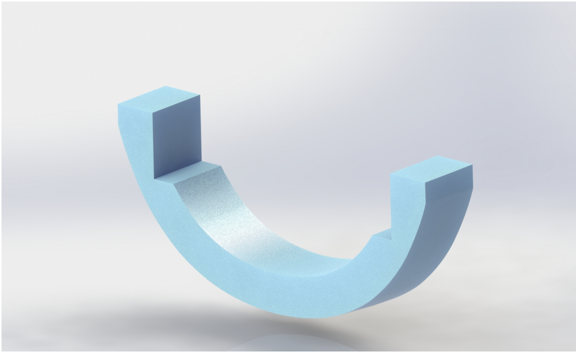

Figure 47: CAD of support hull.

When manufacturing the aluminum piece, first, it would be cut at a length of 2.5 inches. Then the appropriate holes would be drilled for the screws attaching the aluminum piece to the hinge and the skate bearing (see Figure 48). After screwing the hinge onto the aluminum piece, we would put it against the support hull for appropriate adjustments.

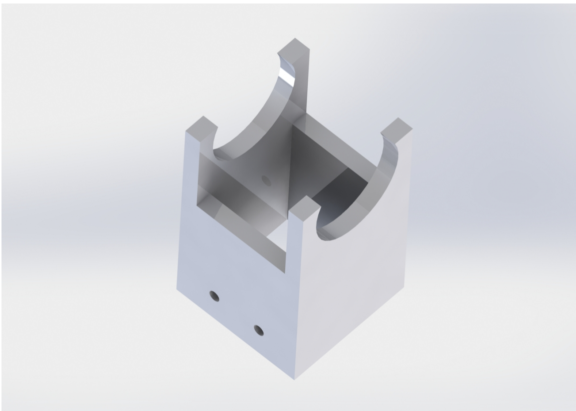

Figure 48: CAD of the Aluminum Tube properly machined.

The servo gear will require machining as well. The hub of the gear would be machined off and the inner shaft diameter would be widened to 0.5 inches through drilling (See Figure 49). Then we would epoxy the ball bearings onto the aluminum piece, and thread the aluminum through the ball bearing and gear. The completed tension arm would then be screwed or epoxied onto the support hull appropriately. On the opposing side, the same tensioning arm would be recreated, but flipped horizontally.

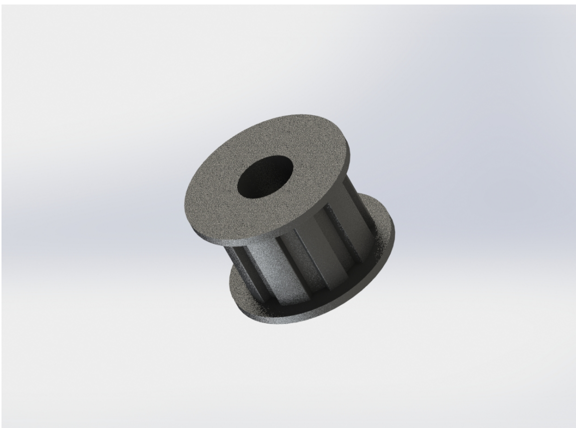

Figure 49: CAD of servo gear machined.

5.5.7 Contingency Plan

(Jennifer Lee)

Due to lack of testing, this final iteration is not necessarily perfect. In order to compensate for any future failures, we analyzed the failure modes and effects. One of the biggest modes of failure can be caused by the amount of tension applied to the belt system.

The first problem to this is high or low spring tension. Fortunately, to mitigate this problem, the hinge's spring is interchangeable. This allows the spring to be switched out with the torsion springs chosen last semester (see Figure 50 and Figure 51). Those springs have been appropriately measured and calculated to have the correct tension power (See Table 4).

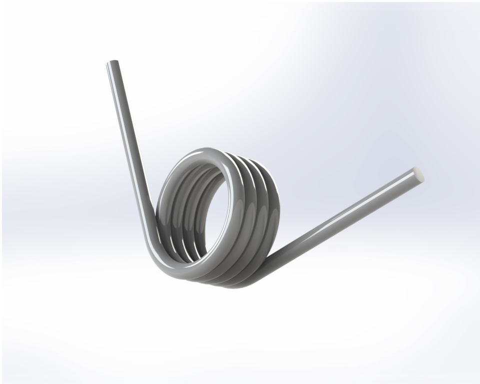

Figure 50: CAD of the finalized torsion spring with leg lengths machined off

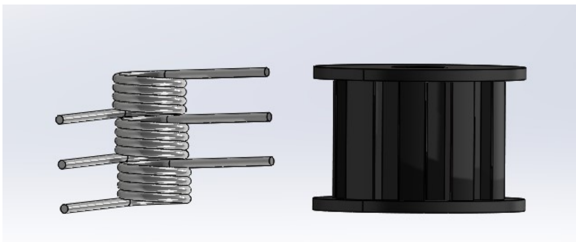

Figure 51: CAD of the finalized stack of torsion spring, size comparison to CAD of finalized gear

Table 4: Finalized Torsion Spring Specifications

Deflection Angle	90
Outer Diameter	0.499 in
Shaft Diameter	0.296 in
Wire Diameter	0.059 in
Number of Coils	4.25
Maximum Torque	4.5 in.-lbs

Furthermore, in case the hinge itself does not work, a crude hinge mechanism can be manufactured with aluminum stock and rods. In fact, the hinge itself can be machined in half and epoxied to a slim piece of aluminum to be remade. The simplest way to mitigate this problem is to adjust the length of the aluminum piece. The screws connecting the aluminum piece to the hinge to the support hull is removable which allows for easy installment and un-installment.

The second problem could be high friction. This includes friction between the gear surface to the ball bearing, the hinge itself, the aluminum piece against the support hull. This can be reduced by making the aluminum piece smaller and attaching the hinge closer to the edge of the aluminum piece. The ball bearings themselves can be sanded down to be thinner and so can the gear itself.

We have accounted for this by having a small gap in between the gear and the ball bearings (See Figure 52), but this is not confirmed due to the lack of a physical model. The hinge itself can be greased.

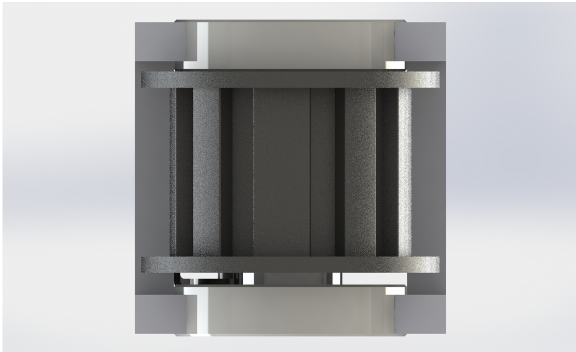

Figure 52: Gap between the gear and ball bearings with shaft in between.

Another problem that can arise is the torque the tension forces can create. If the 3D printed part is not durable enough, the forces can create a twisting motion which can cause the 3D part to dislodge or even break. This can be mitigated with aluminum reinforcements on one side. The support hull was designed to be thinner than the space available to allow reinforcements after epoxying.

5.5.8 Future Steps

(Jennifer Lee)

The most important step to take is the execution of the manufacturing plan and testing. Some aspects of the tensioning arm to examine are dimensions of the parts, integration with the motor control, testing the tension and torsional forces, and adjusting the design as necessary. Although measured and calculated, the dimensions are yet to be precise. Due to the unavailability of the physical motor control assembly, it is impossible to correctly assume the measurements of each of the components, especially the support hull. Thus, adjustments will be necessary. Furthermore, when integrating the belt tensioner with the remaining components of the motor control, there will be incompatibility with parts. This may require further adjustments in measurements, design, or materials. Finally in the testing phase, the functionality and durability of each of the components can be tested. If there are any complications, there will be appropriate accommodations made to the design.