4.3.5 Drive Belt Tensioner

(Jennifer Lee)

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 37 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.

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 37).

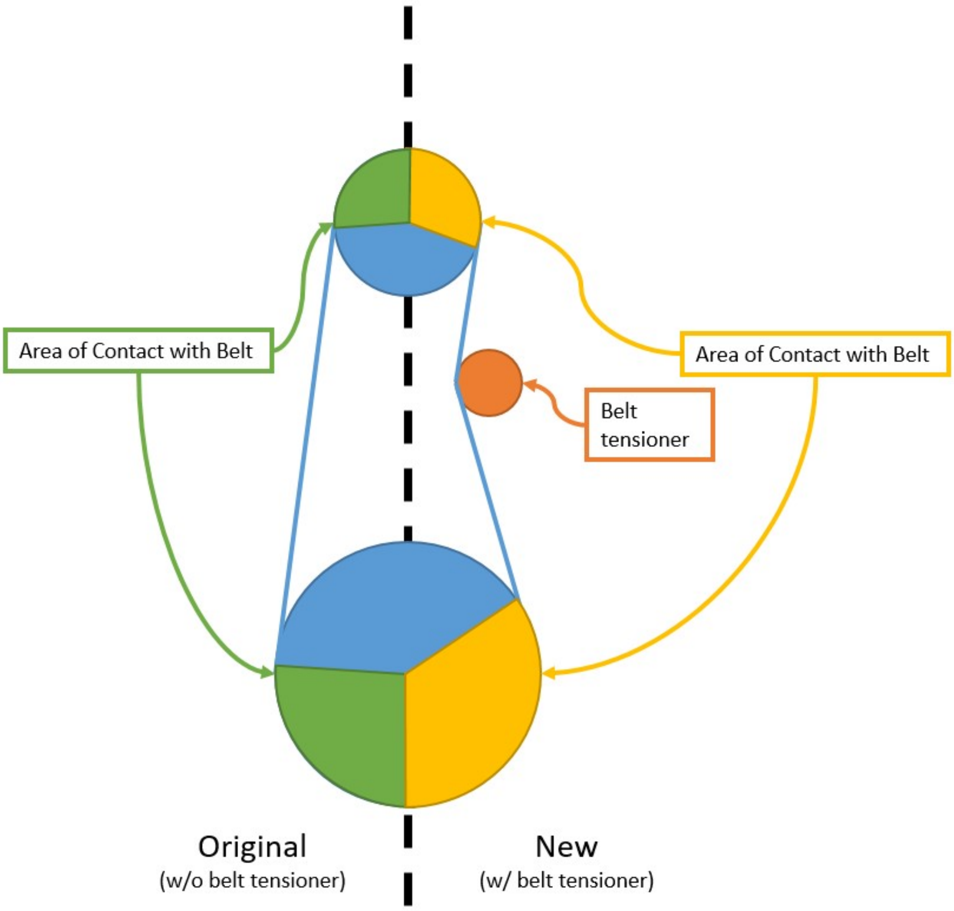

Figure 37: Graphic of belt tensioner's effect on belt tension and area of contact.

Design

Design Constraints

(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. The distance between the two pulleys were about 5 in and the timing-L-belt had a width of about 0.75 in (see figure 21 and 38)

From these approximations, we were able to calculate the deflection of the belt as well as the tension adjustment necessary for the tensioning pulley 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

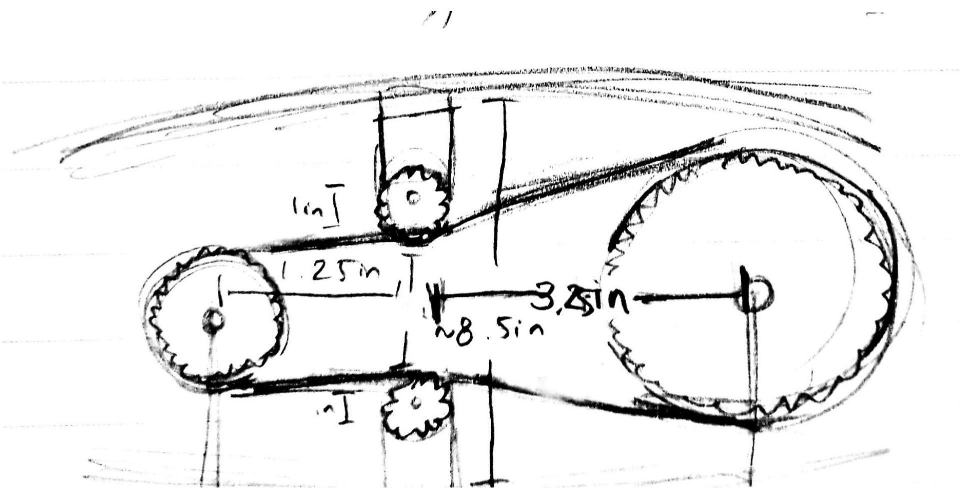

Figure 38: Motor control belt system measurement approximations

Design Goals

(Jennifer Lee)

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

Preliminary Design

(Jennifer Lee)

When designing the preliminary design, there were 2 basic frameworks being considered (see Figure 39). The preliminary design expands upon the box idea pictured. The hinge idea focuses on a more exposed spring, as the box design internalizes the spring and compacts the mechanism. Thus, for the preliminary design, we approached the belt tensioner with the box design in mind. When approaching the box design, we compared a 1 support, 2 springs design and a 2 supports, 1 spring design (see Figure 40). Because of the complexity of the 2 spring design, and the manufacturing and assembling simplicity of the 1 spring design, the 1 spring design was optimal.

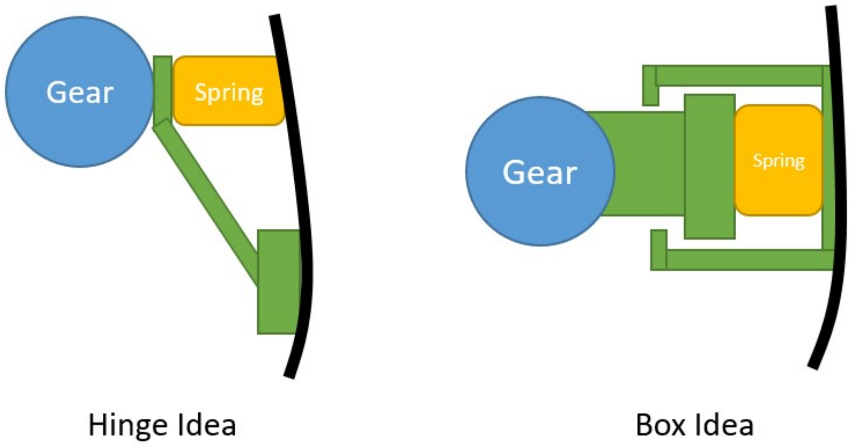

Figure 39: The two basic frameworks considered

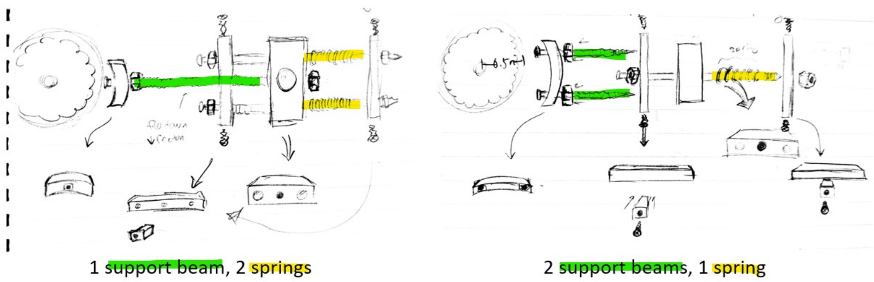

Figure 40: Comparing the two different box design ideas

In order to make the design adjustable and more flexible, we decided upon a frame support for the belt tensioner so that upon adjusting measurements, the gear case is easily replaceable. We also decided upon 2 belt tensioner on each side of the hull for symmetry and to lower the tension necessary for each belt tensioner (see Figure 41). We also decided upon epoxying the main support frame to the hull and screwing the gear cases, also for easy adjustment. Figure 42 is the theoretical and rough CAD of the gear case.

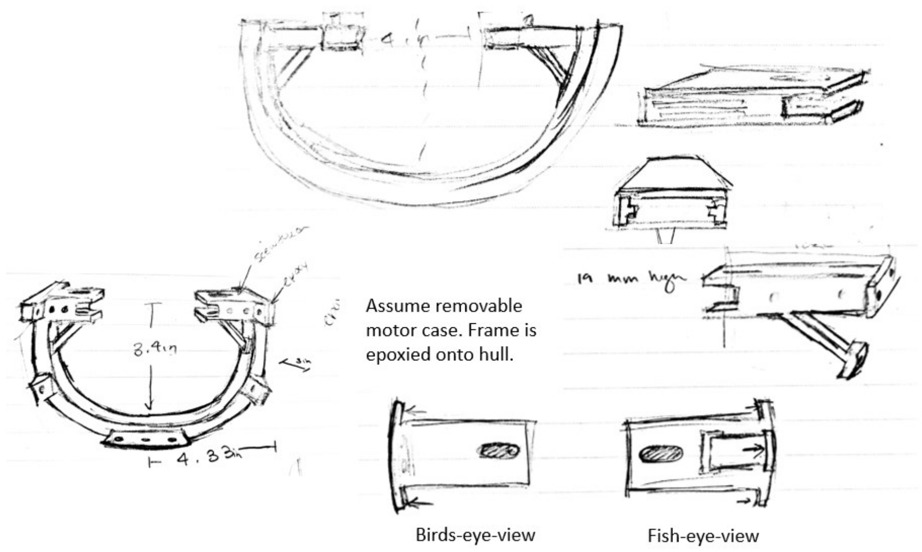

Figure 41: Frame support and gear case sketches

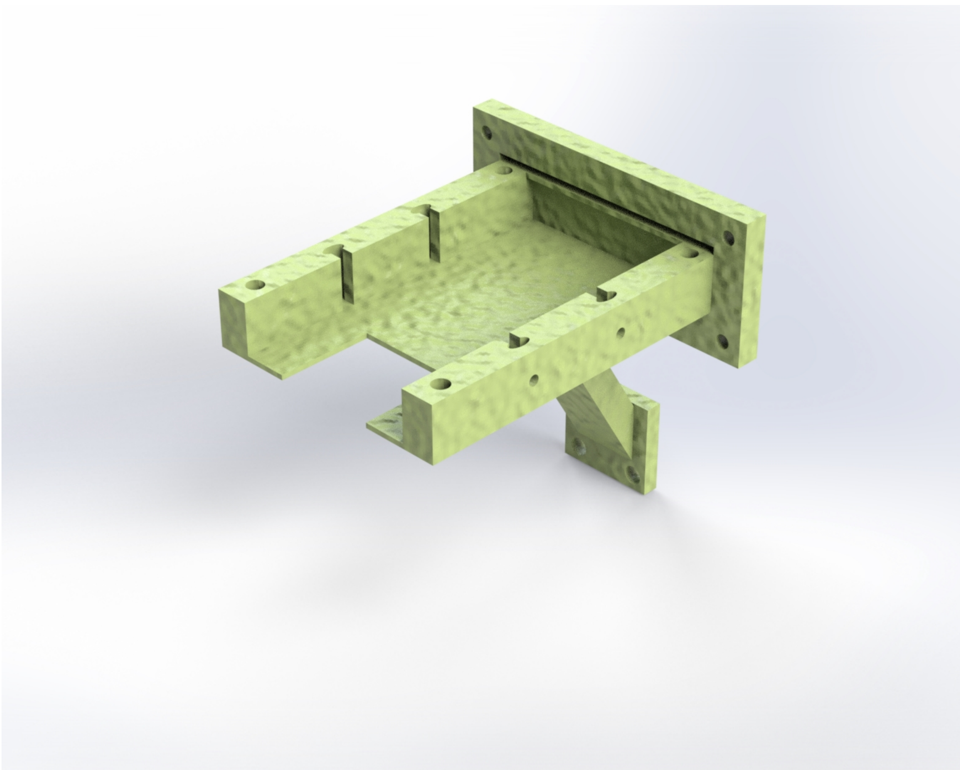

Figure 42: Rough CAD of gear case

Once finalizing the gear used for the motor control system, we also designed a method of assembling the tensioner arm for the gear (see Figure 43). See finalized decision for belt tensioning gear in Figure 44 and the specifications for the finalized tensioning gear in Table 3.

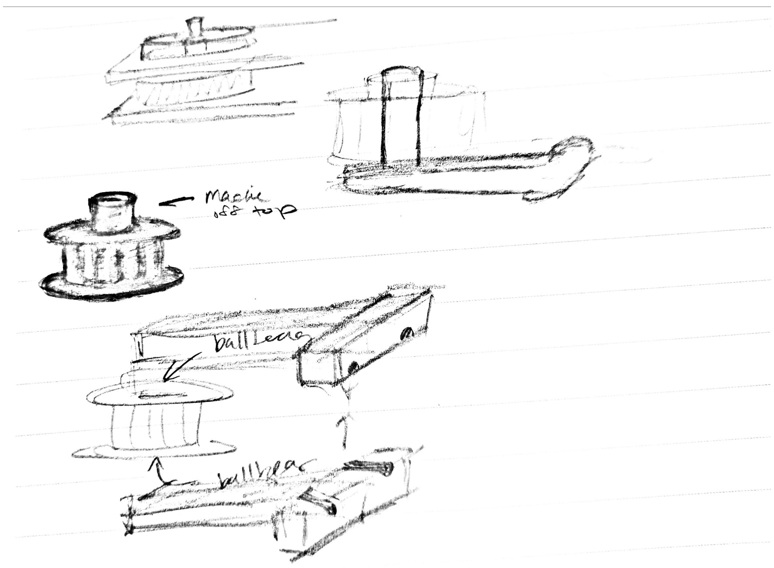

Figure 43: Sketch of tensioner arm design and potential assembly method

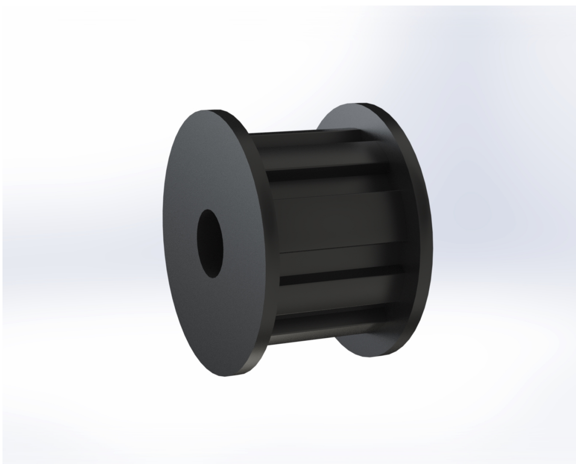

Figure 44: CAD of the finalized gear flange machined off

Table 3: Finalized Belt Tensioning Gear Specifications

Pitch	.375" (L)
Material	Poly-carbonate
No. of Grooves	10
Bore Size	0.375 inches
Pitch Diameter	1.194 inch
Outside Diameter	1.164 inch

Problems with Preliminary Design

(Jennifer Lee)

When observing the preliminary design's potential issues, first and foremost, the scale of the box idea (about a 1 inch by 1.5 inch box) required screws and moving parts which were close to 2 millimeters in size. This caused huge inaccuracies especially if the method of manufacturing was 3D printing. The box idea also had too many moving parts, requiring the accuracy of both size, shape, and efficiency of each part. Each part creates a point of weakness/ a point of potential failure causing this design to be highly inefficient and unprofitable.

Critical Design
(Jennifer Lee)
To reduce the number of moving parts, the critical design expands upon the hinge idea from Figure 39. The two options for the hinge idea was the decision to have the spring external or internal (see Figure 45). 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.

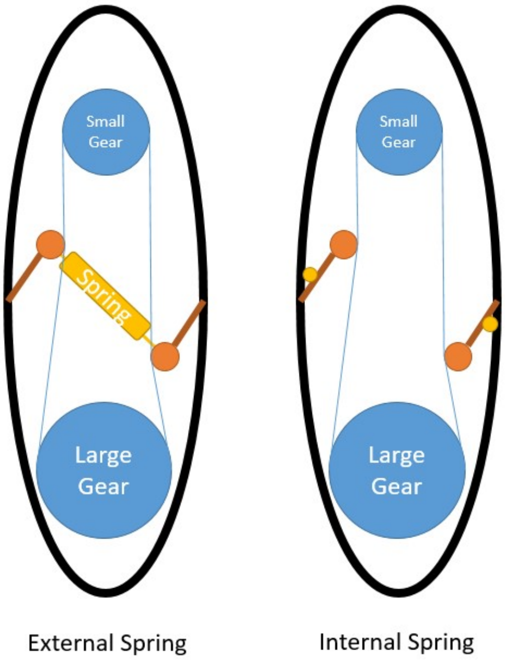

Figure 45: The basic externalized and internalized spring graphic. Orange is the belt tensioning gear system as the yellow represents the springs. The blue is the original motor control system (belt, small gear, large gear).

Currently the hinge design is separated into 3 separate parts: the tensioner base, the tensioner arm, and the screw-rod (see Figure 46 for general assembly). The tensioner base's purpose is to standardize and regulate the movement of the belt tensioner within 90 degrees and level to the x-axis (see Figure 47). The tensioner arm holds and attaches to the gear itself with two ball bearings and 2 pins (see Figure 48). The screw-rod is the rod that holds together the springs, the tensioner arm, and the tensioner base together, but allows concentric rotational movement (see Figure 49).

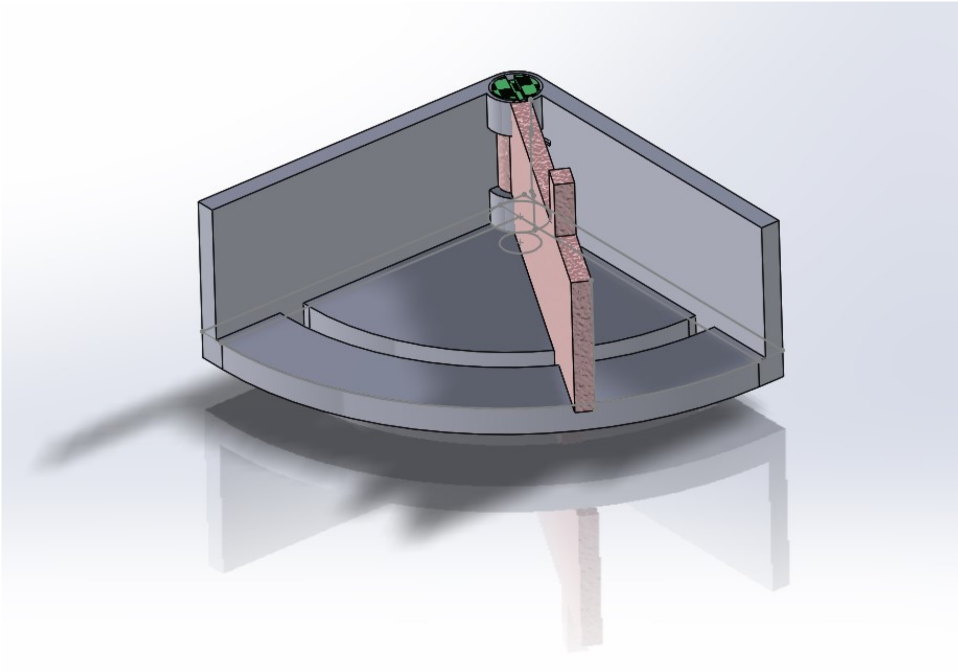

Figure 46: A rough CAD assembly of hinge idea

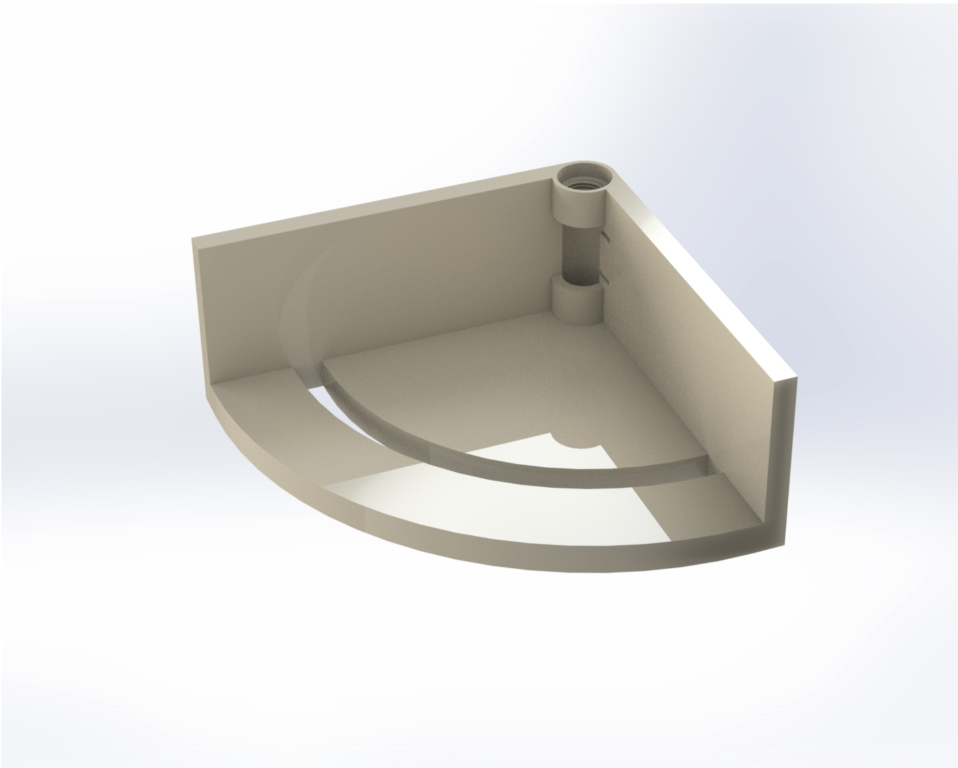

Figure 47: Rough CAD of tensioner base

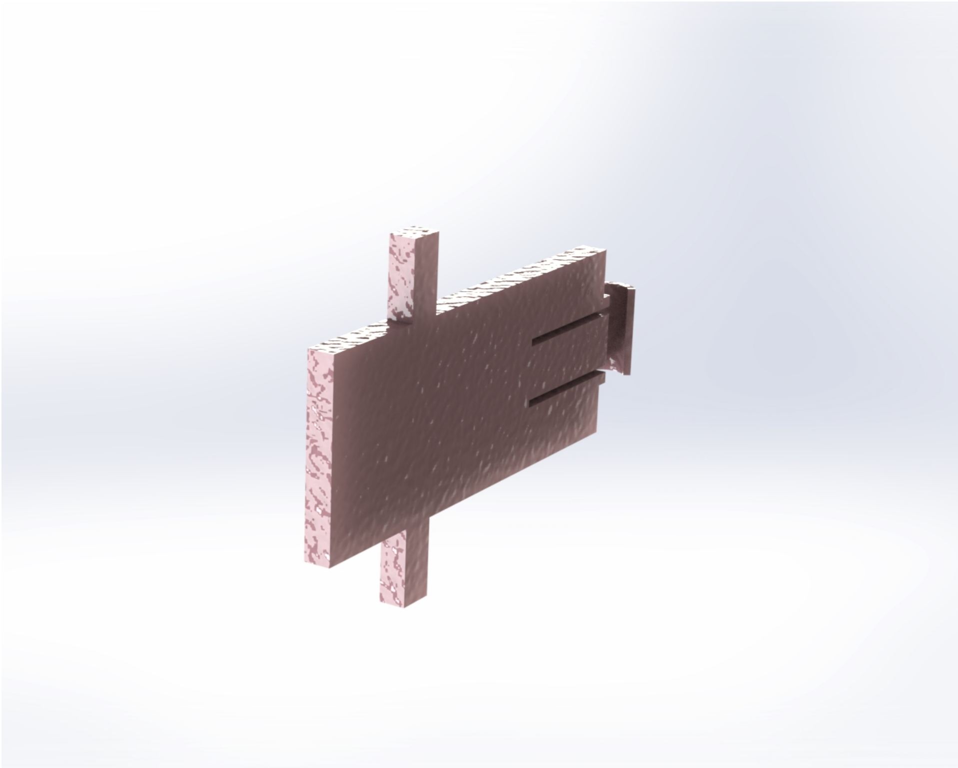

Figure 48: Rough CAD of tensioner arm without the new gear head, bearings, and pins

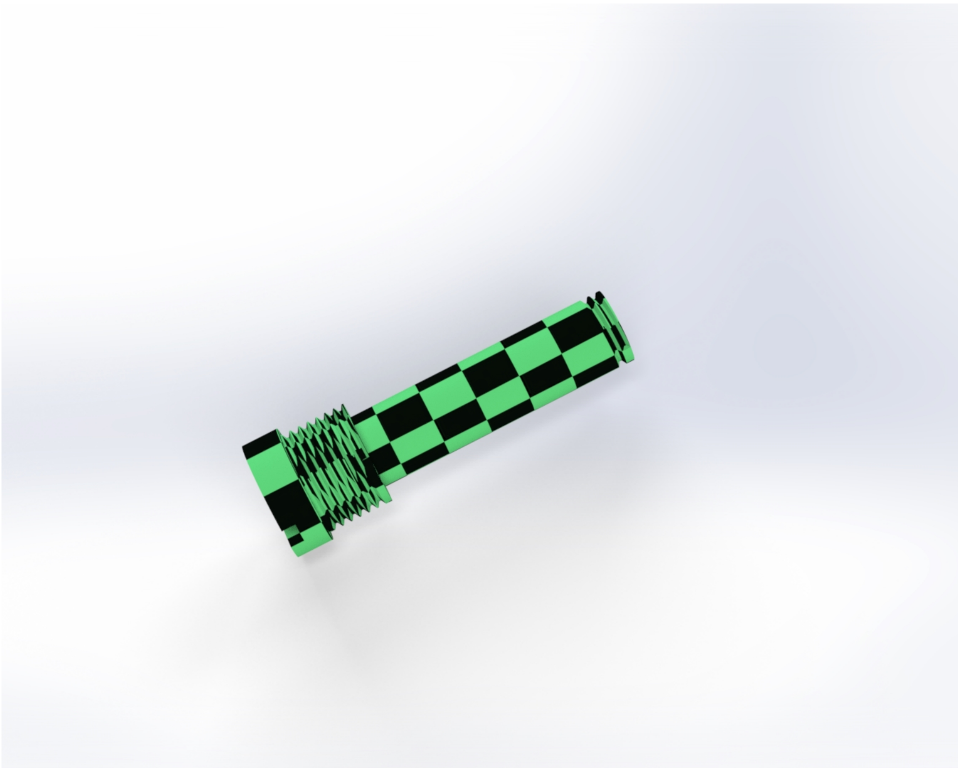

Figure 49: Rough CAD of screw-rod

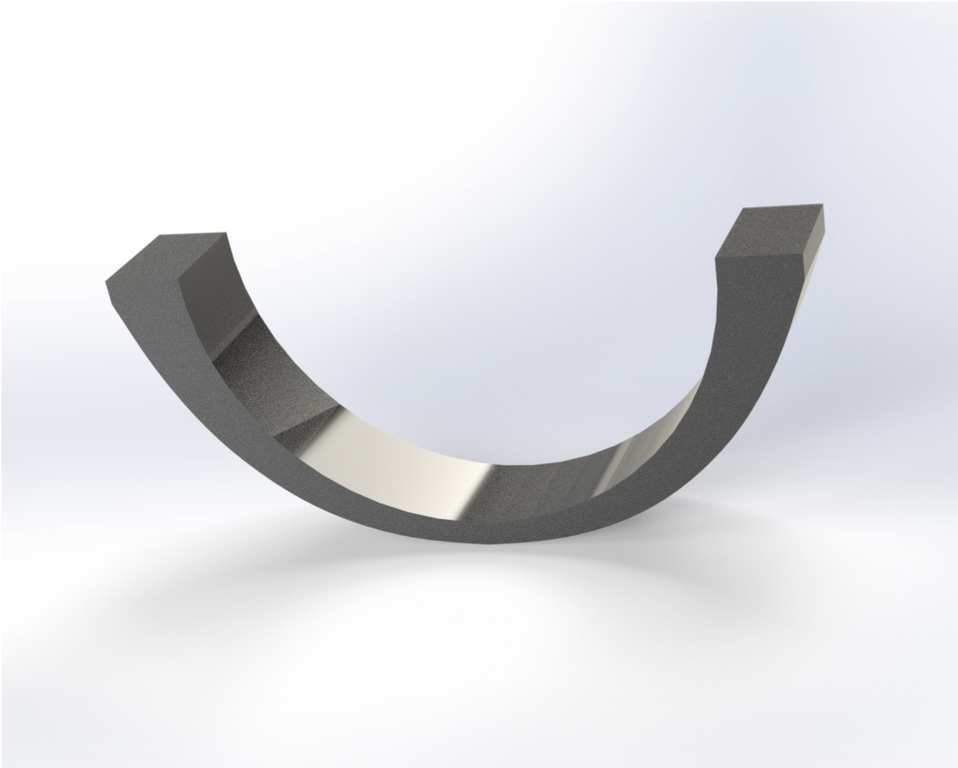

Figure 50: Rough CAD of supporting frame. Removed asymmetrical arch for easy measurement and estimations

Some design elements we are keeping consistent is the hull support frame (see Figure 50) and the removable element of the direct attachments. We still run into the issue of the scale of the parts. For example, if we keep the current dimensions, the screw-rod becomes about 0.148 in (approx 4 mm) in diameter. However, by finalizing the torsion spring used in the design, we are now able to test if the screw-rod is entirely necessarily or not as the tension within the springs can hold the tensioner arm and base together. Due to some difficulty regarding finding a torsion spring with both small dimensions and adequate, we decided upon stacking 3 smaller springs into 1 hinge, causing the hinge to be taller but not necessarily wider (see Figure 51 and Figure 52 for image of finalized spring) (see Table 4 for the spring specifications).

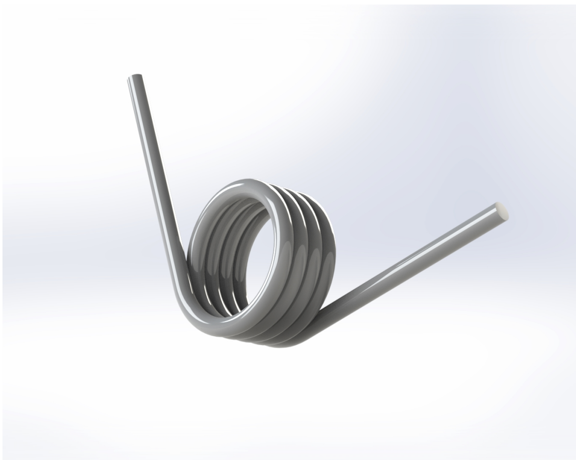

Figure 51: CAD of the finalized torsion spring with leg lengths machined off

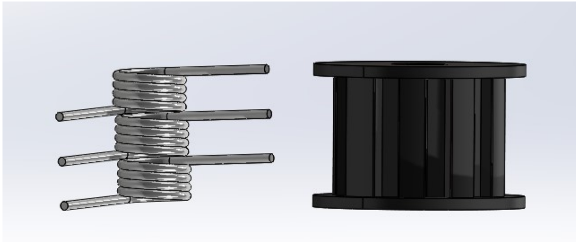

Figure 52: CAD of the finalized stack of torsion spring, size comparison to CAD of finalized gear

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

Manufacturing

(Jennifer Lee)

Most of the manufacturing was done by 3D printing, but because the pieces were too small, the dimensions were inaccurate and rough. Thus, depending on the purpose of each piece, the base will be 3D printed, the tensioner arm will be cut from acrylic, and the screw-rod maybe made from aluminum or scrapped all-together. When detailing the assembly of each of the pieces, there will be inserted threads for the tensioner base so that it will be easily screwed onto the hull support frame as the support frame itself is epoxied onto the hull directly. This prevents any issues regarding waterproofing.

Future Work

(Jennifer Lee)

All the pieces will be strictly measured to prevent any errors and the springs will be tested so that the manufacturing material for each item can be perfected. Improvements will take several forms. Now that flexibility has been accounted for, we will now focus on durability and efficiency as 3D printed parts cannot withstand the torque and tension the torsion spring will apply onto it for long. Future iterations will transition towards easier to manufacture stronger materials rather than materials that can be used for quick prototyping.

The belt tensioner has also not been integrated within the motor control. Thus, measurements must be tested and made in that regard as well.