# Project 2

*Final Report*

Team 19

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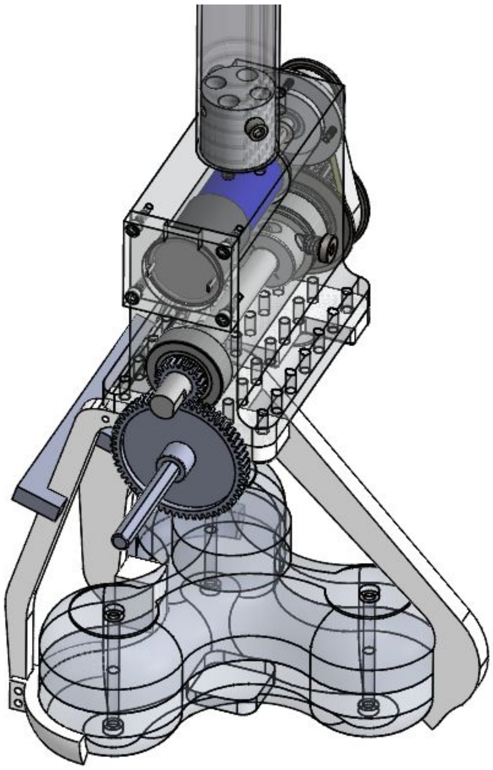
II. Summary

**Isometric Screenshot:**



**Description:**

The assembly is supported by a flat resin block with two rounded, downward tabs. The tabs support bearings for a single D-shaft with an attached moving arm, and three rigid arms are attached directly to the flat base with screws. The three rigid arms are also connected to each other with a horizontal acrylic piece to prevent shifting of individual arms. A small gear is attached to the motor shaft and drives a larger gear on the D-shaft, causing the moving arm to rotate with increased torque. The arm and gears are secured to the shafts using set screws to prevent slipping. The three rigid arms can provide a very large normal force without the need for an additional applied torque, and allow for improved alignment with the object compared to moving arms on both sides. The moving arm has greater torque due to an increased gear ratio and no losses from other moving components, and generates normal forces by pressing the object into the rigid arms.

The grippers are curved to match the sides and lower curvature of the object, which grips it more securely and prevents unwanted shifting during motion of the arm. This shape also allows the gripper to support the object using both upward normal and frictional forces rather than pure frictional forces. The contact points of each arm are also covered with neoprene rubber to provide much greater friction.

**Peak force:** $F_{peak} = 3Mg = 37.5N$ at the bottom of the swing. (Page #12)

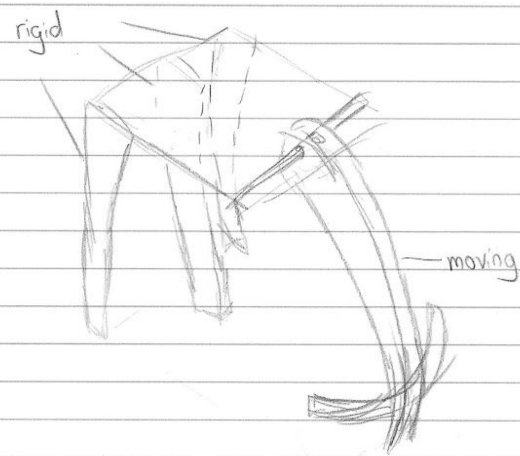
**Factor of safety for gripping the object:** FoS = 1.24 (Page #16)

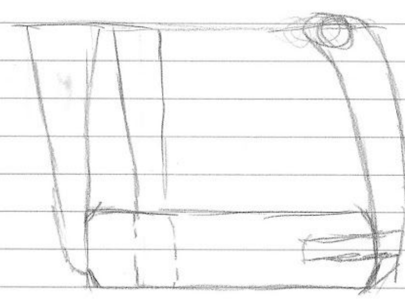
**Factor of safety for component failure:** FoS = 1.91 (Page #18)

**Weakest link:** The weakest link is in the left pushing arm connected to the mount due to contact stress concentrations. Design might fail due to deformation in that arm.

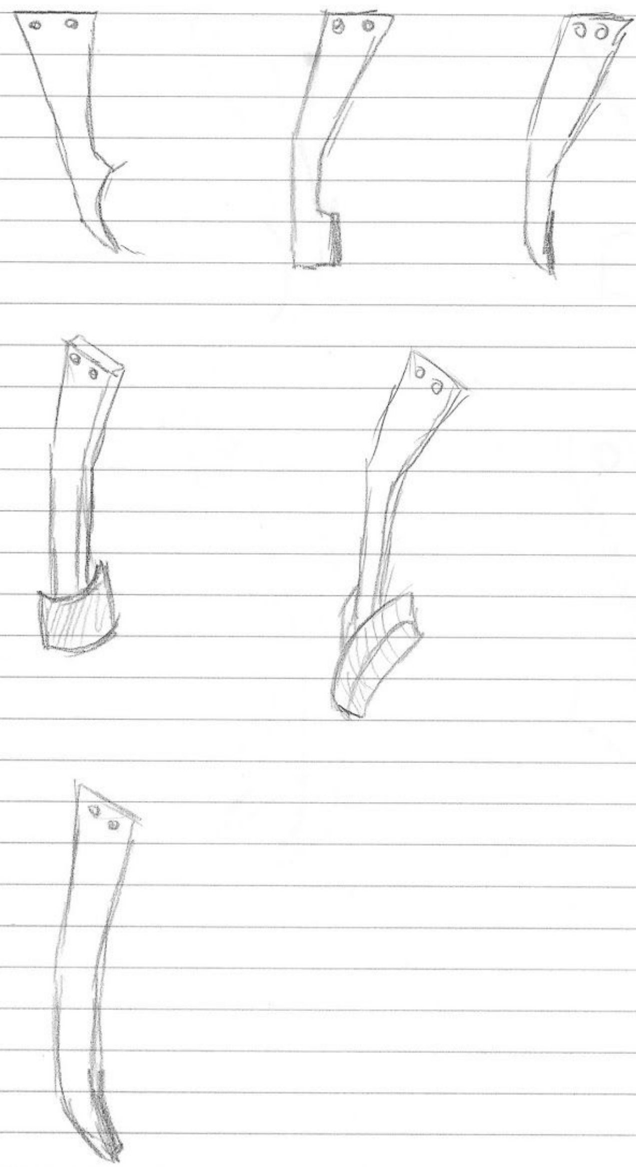
III. Conceptual Design Sketches

A) Conceptual Design One

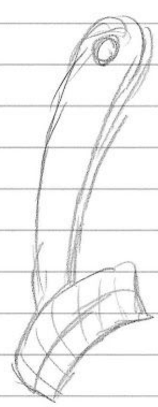


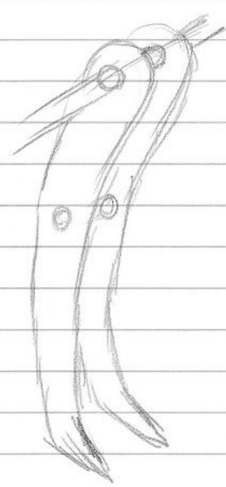



Rigid arm ideas

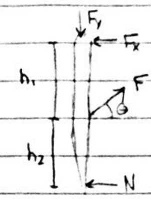


Moving arm ideas





Alternate design




$$\sum M|_{pin} = -N(h_1+h_2) + F\cos\Theta \cdot h_1 = 0$$

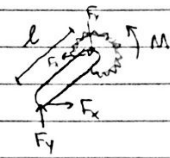
$$F = \frac{N(h_1+h_2)}{h_1\cos\Theta} = \frac{N}{\cos\Theta}\left(1+\frac{h_2}{h_1}\right)$$

$$\sum F_y = F\sin\Theta - F_y = 0$$

$$F_y = N\tan\Theta\left(1+\frac{h_2}{h_1}\right)$$

$$\sum F_x = F\cos\Theta - N - F_x = 0$$

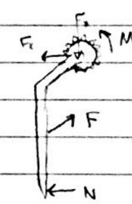
$$F_x = N\left(1+\frac{h_2}{h_1}\right) - N = N\cdot\frac{h_2}{h_1}$$




$$\sum M|_{gear} = M - F_y \cdot l\cos\Theta + F_x \cdot l\sin\Theta = 0$$

$$M = N\tan\Theta\left(1+\frac{h_2}{h_1}\right) l\cos\Theta - N\frac{h_2}{h_1}\, l\sin\Theta$$

$$= Nl\sin\Theta\left(1+\frac{h_2}{h_1}\right) - Nl\sin\Theta\left(\frac{h_2}{h_1}\right) = Nl\sin\Theta$$




$$\sum M|_{gear} = -N(h_1+h_2+l\sin\Theta) - F\sin\Theta(l\cos\Theta)$$

$$+ F\cos\Theta(h_1+l\sin\Theta) + M = 0$$

$$M = N(h_1+h_2+l\sin\Theta) + N\tan\Theta\left(1+\frac{h_2}{h_1}\right)(l\cos\Theta)$$

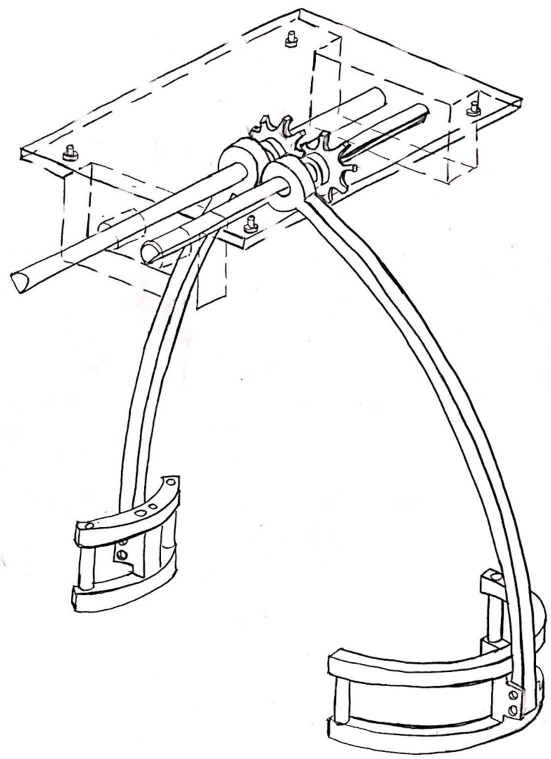
$$- N\left(1+\frac{h_2}{h_1}\right)(h_1+l\sin\Theta)$$

$$= N(h_1+h_2+l\sin\Theta) + Nl\sin\Theta\left(1+\frac{h_2}{h_1}\right) - N\left(h_1 + l\sin\Theta + h_2 + \frac{h_2}{h_1}l\sin\Theta\right)$$

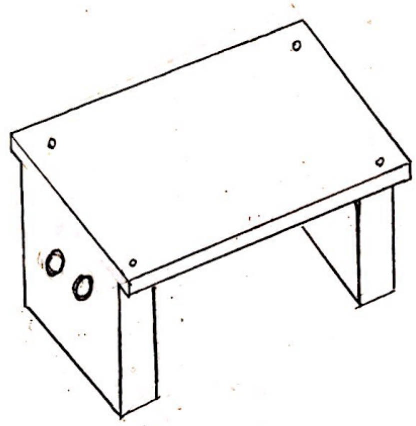
$$= N\left(h_1 + h_2 + l\sin\Theta + l\sin\Theta - \frac{h_2}{h_1}l\sin\Theta - h_1 - l\sin\Theta - h_2 - \frac{h_2}{h_1}l\sin\Theta\right)$$

$$= Nl\sin\Theta$$

B) Conceptual Design Two

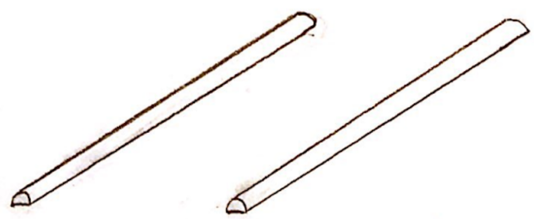


Housing



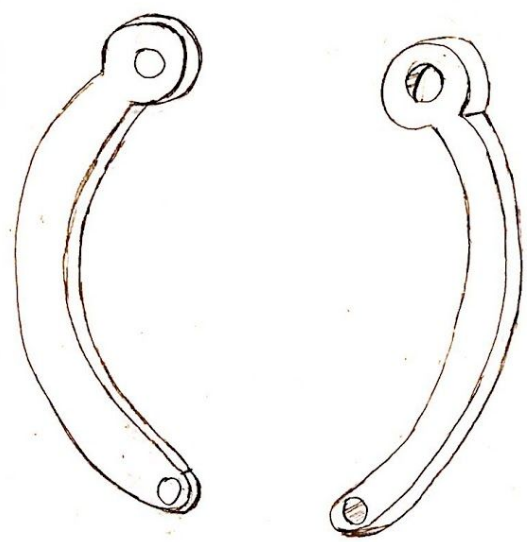
The housing is to used to hold shafts and gears directly.
It will be mounted on the robot wrist.

D-Shafts



We use D-shafts to make rigid connections with gears.

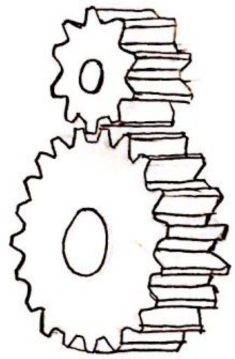
Gripper arms.

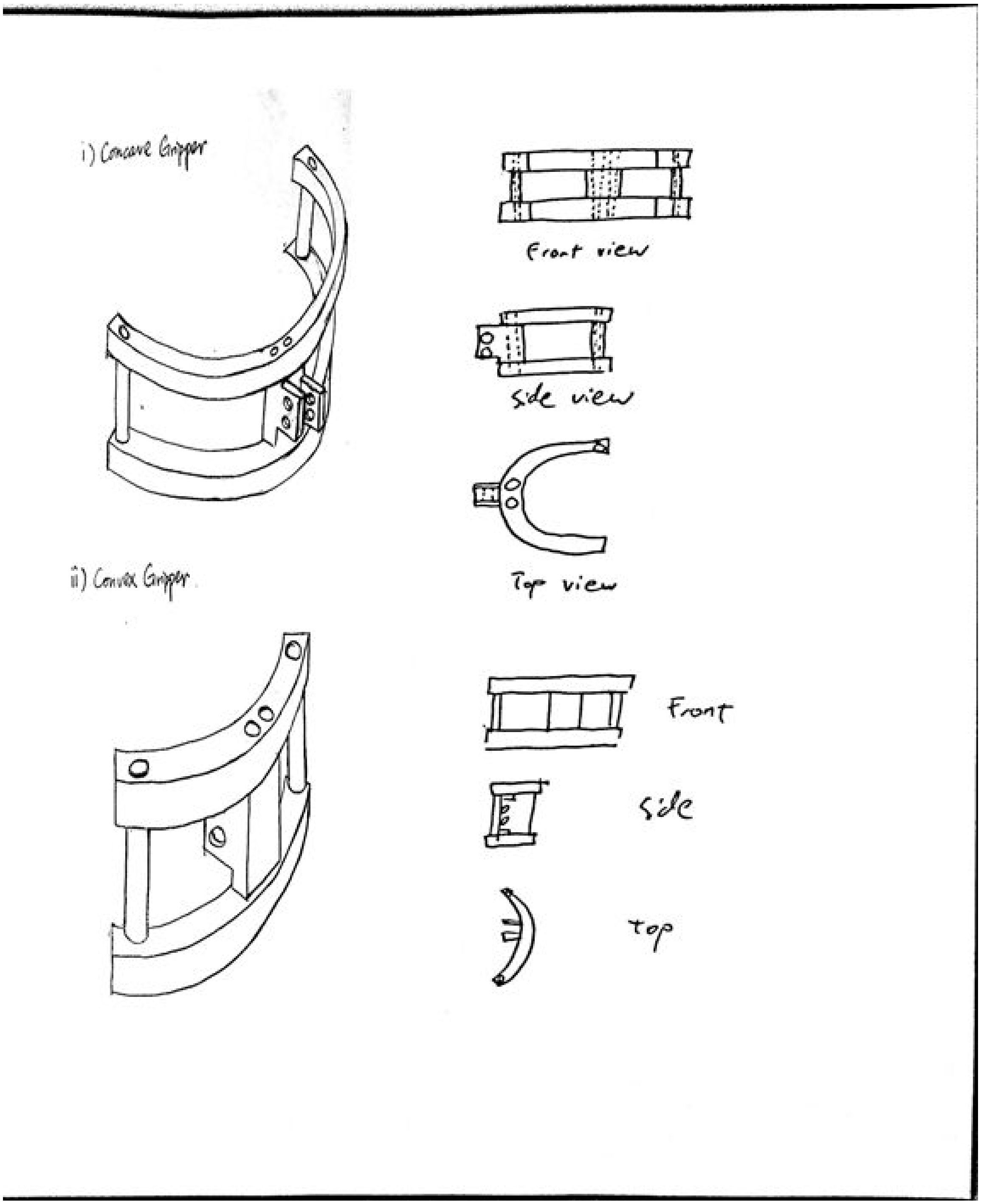


Gripper Arms are curved such that there won't be excess contact with the spinner.

Gear-up Gears.

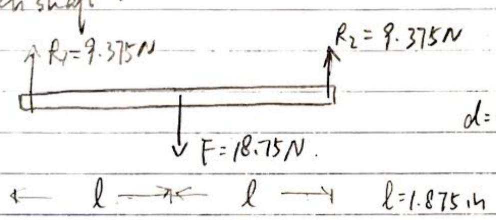
Gear Ratio = 4.84




i) Concave Gripper
Front view
side view
Top view
ii) Convex Gripper.
Front
side
top

Shafts

for each shaft.



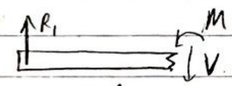

$d = \frac{1}{4}in$

$l = 1.875in$

$\Sigma F = R_1 + R_2 = 18.75N$

$\Sigma M_1 = 0: \quad 2R_2 = F$

$\Rightarrow R_1 = R_2 = \frac{1}{2}F = 9.375N$




$M_{max} = R_1 l$

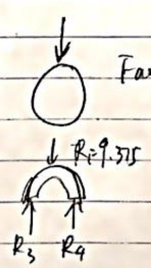
$$\sigma_b = \frac{M_{max}\frac{d}{2}}{\frac{\pi}{4}(\frac{d}{2})^4} = \frac{32 M_{max}}{\pi d^3} = \frac{32 \times 9.375N \times 1.875in}{\pi(\frac{1}{4}in)^3}$$

$$= \frac{32 \times 9.375N \times 0.047625m}{\pi(0.00635m)^3}$$

$= 1.78 \times 10^7 N \cdot m$

$= \boxed{2575.45 psi}$

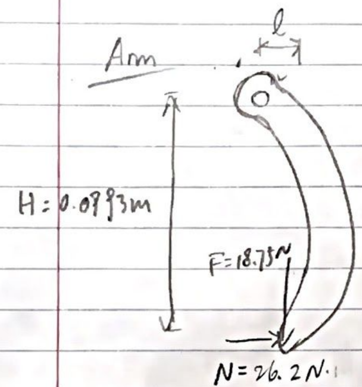
Bearing




$F_{axial} = 9.375N$

$R_3 = R_4 = \frac{9.375N}{2} = 4.69N$

$$\sigma_A = \frac{R_3}{A} = \frac{4.69N}{0.1875in \times 0.065in} = \frac{1.054 lbf}{0.012188 in^2} = \boxed{86.1538 psi}$$




Gear Ratio = 2.

$$\tau = 2\tau_0 = 2 \times 1.3\,N\cdot m = 2.6\,N\cdot m$$

$$N = \frac{\tau}{H} = \frac{2.6\,N\cdot m}{0.0993\,m} = 26.2\,N$$

$$M_{max} = N \cdot H - f \cdot l$$

$$= 26.2\,N \times 0.0993\,m - 18.75\,N \times 0.051\,m$$

$$= 1.70\,N\cdot m$$

$$\sigma_b = \frac{M \cdot y}{I} \approx \frac{M \cdot \frac{0.0127m}{2}}{\frac{1}{12} \cdot 0.00635m\,(0.0127m)^3} \approx 10\,MPa \approx \boxed{1.44\,ksi}$$

Total Force:

$$F_{max} = 3Mg = 3 \times (2.56 + 0.25)\,lbs \times 9.81\,N/kg$$

$$= 3 \times 1.275\,kg \times 9.81\,N/kg$$

$$= 37.5\,N \Rightarrow \frac{F_{max}}{2} = 18.75\,N$$

If $N_L = N_R$, $F_{fL} = F_{fR} = 18.75N$

Assume $\mu = 0.7$, $N \geq 26.8N$

$$\tau = 26.8N \times 3.91in - 18.75N \times 2.02in$$

$$= 26.8N \times 0.0993m - 18.75N \times 0.0513m$$

$$= 1.70\,N\cdot m$$

$$\tau_0 = 1.3\,N\cdot m$$

$$\tau_{max} = 2\tau_0 = 2.6\,N\cdot m$$

$$\tau_{max} = 2.6\,N\cdot m = (N_{max} \times 0.0993m - 0.7N_{max} \times 0.0513m)$$

$$\Rightarrow N_{max} = 41\,N$$

$$f_{max} = 41N \times 0.7 = 28.7N$$

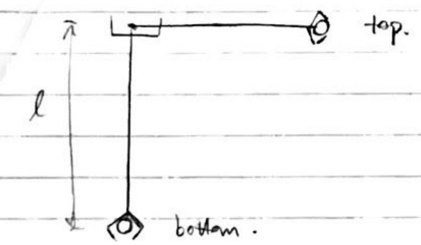
$$fos = \frac{f_{max}}{\frac{F_{max}}{2}} = \frac{28.7N}{18.75N} = \boxed{1.53}$$

IV. Simple Modeling of Candidate Designs

A) Forces & Moments Calculation

$F\_peak = 3*mg = 3*(2.56+0.25)\,lbs*9.81\,N/kg$
$= 3*(1.275\,kg)*9.81\,N/kg$
$= 37.5\,N$ by eq (1)

Dynamic Motion.

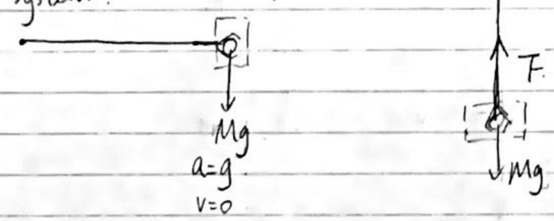



Conservation of Energy.

$mgl = \frac{1}{2} m v_{max}^2$

$v_{max} = \sqrt{2gl}$

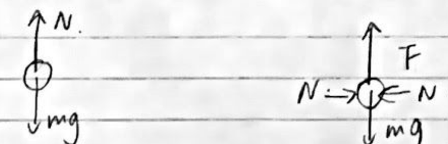
For the system.




$V = V_{max}$

$a = \frac{v^2}{l} = \frac{2gl}{l} = 2g$

For the object




$mg - N = mg \Rightarrow N = 0.$

$F - mg = ma$

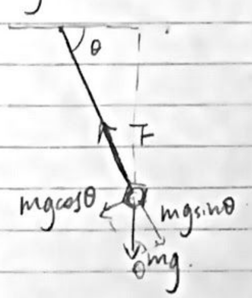
$F - mg = m\frac{v^2}{l}$

$\Rightarrow F = mg + m\cdot\frac{2gl}{l}$

$= 3mg$ (1)

$a = 2g$, upward

At some angle:




$F - mg\sin\theta = m\frac{v^2}{l}$

Conservation of Energy.

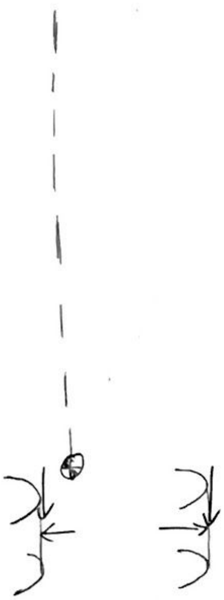
$\frac{1}{2}mv^2 = mgl\sin\theta$

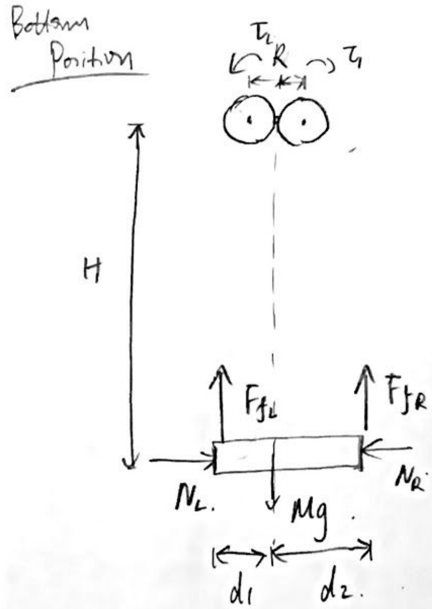
$v = \sqrt{2gl\sin\theta}$

$\Rightarrow F = mg\sin\theta + \frac{m\,2gl\sin\theta}{l}$

$F = 3mg\sin\theta$

$a_r = 2g\sin\theta,\ a_t = g\cos\theta$



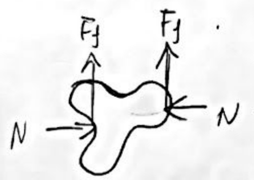



$\Sigma F_x = 0: \quad N_L = N_R \Rightarrow \mu N_L = \mu N_R$

$\Sigma F_y = Ma, \; a = 2g$ upward.

$F_{fL} + F_{fR} - Mg = 2Mg$

$\Rightarrow F_{fL} + F_{fR} = 3Mg$




$\Sigma M = 0: \quad F_{fL} \cdot d_1 = F_{fR} \cdot d_2$

$F_{fL} = \frac{d_2}{d_1} F_{fR} > F_{fR}$ — We should have $\mu N_L \geq F_{fL}$

$\Rightarrow$ Larger friction force on the left.

$$\begin{cases} F_{fL} = \frac{3d_2}{d_1+d_2} Mg \\ F_{fR} = \frac{3d_1}{d_1+d_2} Mg \end{cases}$$

$N_L = \frac{3d_2}{d_1+d_2} \cdot \frac{Mg}{\mu}$

$N_R = \frac{3d_1}{d_1+d_2} \cdot \frac{Mg}{\mu}$

For the left gear:

$$\boxed{\tau_2 = N_L \cdot H - F_{fL} \cdot (d_1 - R)}$$

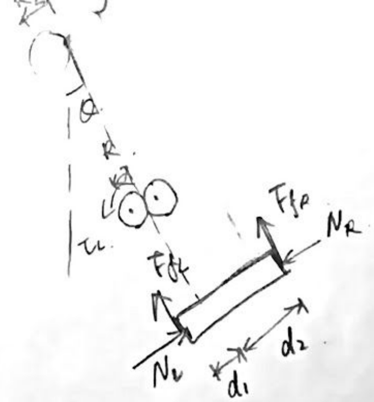
$\tau_L = N_L \cdot H - \frac{3d_2}{d_1+d_2}(d_1 - R)$

$\tau_R = N_R H - \frac{3d_1}{d_1+d_2}(d_2 - R)$

$\tau_L = \frac{3d_2}{d_1+d_2}$ *Mg/μ*(H-d1+R)

$\tau_R = \frac{3d_1}{d_1+d_2}$ *Mg/μ*(H-d2+R)

At some angle.




$a_t = g\sin\theta$.

$N_R - N_L = mg\sin\theta$.

$N_R = N_L + mg\sin\theta$. $N_L < N_R$.

$\mu N_L < \mu N_R$.

Energy Balance. $\frac{1}{2}mv^2 = mgl\cos\theta$.

$V = \sqrt{2gl\cos\theta}$.

$F_{fL} + F_{fR} - mg\cos\theta = m \cdot 2g\cos\theta$

$F_{fL} + F_{fR} = 3mg\cos\theta$

$\Sigma M = 0$: $F_{fL} \cdot d_1 = F_{fR} \cdot d_2$. $d_1 < d_2$ $F_{fL} > F_{fR}$.

$F_{fL} = \frac{d_2}{d_1} F_{fR}$. $F_{fL} \geq \mu N_L$.

$$\begin{cases} F_{fL} = \frac{3d_2}{d_1+d_2} mg\cos\theta \\ F_{fR} = \frac{3d_1}{d_1+d_2} mg\cos\theta \end{cases}$$

$$\begin{cases} \tau_L = N_L \cdot H - F_{fL}(d_1 - R) = N_L H - \frac{3d_2}{d_1+d_2} mg\cos\theta \\ \tau_R = N_R H - F_{fR}(d_2 - R) = N_R H - \frac{3d_1}{d_1+d_2} mg\cos\theta \end{cases}$$

If $\theta = \frac{\pi}{2}$. $\sin\theta = 1$. $\cos\theta = 0$.

$N_R = mg + N_L$.

$\tau_R = (mg + N_L)H$ If $N_L = 0 \Rightarrow mgH$.

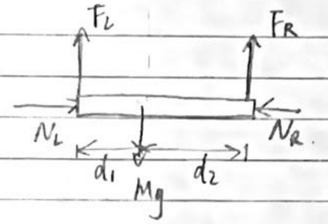
(Almost open)

$\tau_L = 0$.

$\circlearrowright\ \tau = \tau_0 \cdot 3 = 3.9\,N\,m$.

H

Lowest Point: 3g Acceleration Upward




$d_1 : d_2 = 1in : 3in = 1 : 3$.

$F_L = \frac{3 d_2}{d_1 + d_2} mg = \frac{9}{4} mg = 28.1N$

$F_R = \frac{3 d_1}{d_1 + d_2} = \frac{3}{4} mg = 9.4N$.

$\tau = 3.9\ N \cdot m$, $N_R = \frac{\tau}{H} \approx 39N$. $f_{R\,max} = \mu N_R = 11.7N$.
$H = 0.0993m$. $\mu = 0.3$

| |
|---|
| $\Sigma F_x = 0$: $N_L = N_R = 39N$. |
| $\Sigma F_y = 3Mg, \uparrow$: $F_L = \frac{9}{4} mg = 28.1N$. $F_R = \frac{3}{4} mg = 9.4N$. |

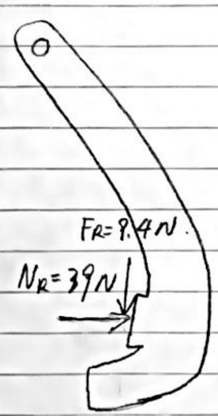
Left Arm (Each).

$f_{L\,max} = 11.7N$

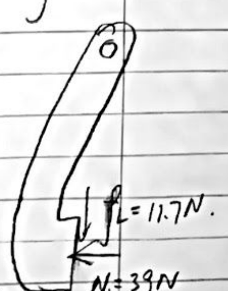
$F_{L,Arm} = \frac{F_L - f_{L\,max}}{2} = \frac{28.1N - 11.7N}{2}$

$\Rightarrow F_{L,Arm} = 8.2N$.

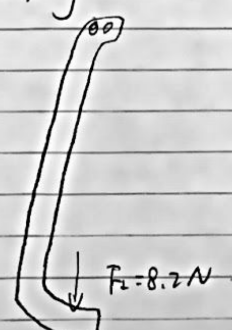
Right Arm:




Pushing Arm:




Lifting Arm:




$F_R$ can be supported from a combination of friction and normal forces.

Total Force.

$F_{max} = 3Mg = 3 \times (2.56 + 0.75)\,lb \times 9.8 N/kg$

$= 3 \times 1.275\,kg \times 9.8 N/kg$

$= 37.5 N$

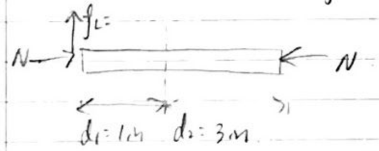
$\tau_0 = 1.3 N\cdot m$

$\tau_{max} = 3\tau_0 = 3.9 N\,m$.

$N = \frac{\tau_{max}}{H} = \frac{3.9 N\cdot m}{0.0993 m} = 39 N$.

Assume $\mu = 0.3$, $f_{max} = \mu N = 0.3 \times 39N = 11.7N$

Needed:




$F_L = \frac{3d_2}{d_1+d_2} mg = 28.1N$.

$F_R = \frac{3d_1}{d_1+d_2} = 9.4N$.

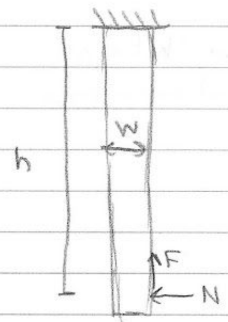
Since the left side of the fidget spinner can be secured by normal force, we need to have enough friction force on the right side to ensure the fidget spinner does not slip!

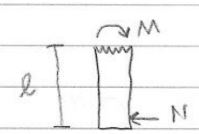
$FoS = \frac{f_{max}}{f_R} = \frac{11.7N}{9.4N} = \boxed{1.24}$

B) Stresses Calculation

Rigid arms estimates

-Single arm,




$$M = N \cdot \ell$$

$$\sigma = \frac{My}{I} = \frac{N \cdot \ell \cdot \frac{w}{2}}{\frac{w^3 t}{12}} = \frac{6N\ell}{w^2 t}$$

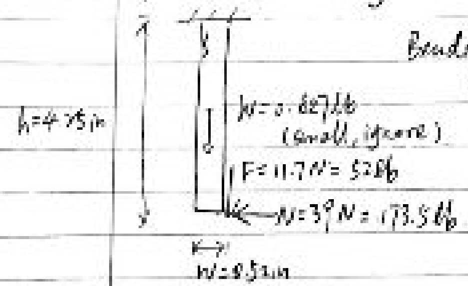
$$\sigma_{max} = \frac{6Nh}{w^2 t}$$

$$w = \sqrt{\frac{6Nh \cdot fos}{\sigma_y \cdot t}}$$

The three left rigid arms are designed such that one pushing arm will provide vertical upward force by friction, and the other two lifting arms will provide vertical upward forces by normal forces exerted by fillet contact bumpers.

Based on previous page.

i) for left rigid pushing arm. Material: Photopolymer Resin (Clear) $\sigma_Y = 9380\ psi$.




Bending Stress: $\sigma_b = \frac{6Nh}{w^2} = \frac{6 \times 5.2lb \times 4.25in}{(0.52in)^2} = 4.9ksi$.

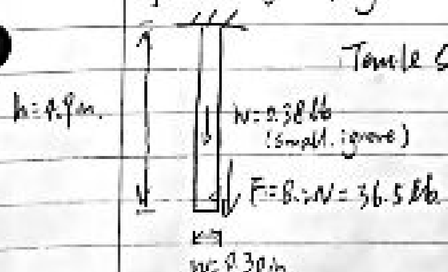
$FoS_b = \frac{\sigma_Y}{\sigma_b} = \frac{9.380ksi}{4.9ksi} = \boxed{1.91}$

Tensile Stress: $\sigma_a = \frac{F}{wt} = \frac{5.2lb}{0.52in \times 0.25in} = 400\ psi$

$FoS_a = \frac{\sigma_Y}{\sigma_a} = \frac{9380\ psi}{400\ psi} = \boxed{23.45}$.

$\Rightarrow$ $\boxed{FoS = 1.91 \text{ for left pushing arm}}$

ii) for left rigid lifting arms: Material: Acrylic $\sigma_Y = 10.59\ ksi$. (for each arm).

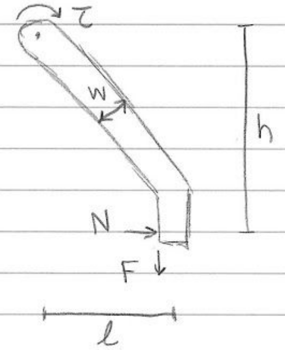



Tensile Stress: $\sigma_a = \frac{F}{wt} = \frac{36.5lb}{0.30in \times 0.25in} = 487\ psi$.

$FoS_a = \frac{\sigma_Y}{\sigma_a} = \frac{10.57ksi}{487psi} = \boxed{21.7}$

$\Rightarrow$ $\boxed{FoS = 21.7 \text{ for left lifting arms}}$.

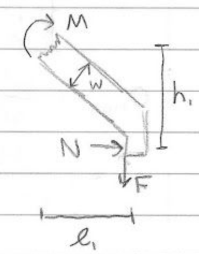
## Moving arm estimates




F includes friction and downward normal forces

$\tau = Nh - Fl$

*increased friction forces and downward normal forces reduce required torque



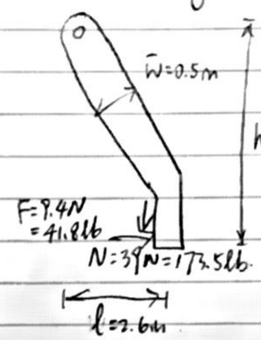

$M = Nh_1 - Fl_1$

$$\sigma_b = \frac{(Nh_1 - Fl_1)\cdot\frac{w}{2}}{\frac{w^3t}{12}} = \frac{6(Nh_1 - Fl_1)}{w^2t}$$

$$\sigma_{base} = \frac{6(Nh - Fl)}{w^2t}$$

$$W_{base} = \sqrt{\frac{6(Nh - Fl)\cdot fos}{\sigma_y \cdot t}}$$

iii) Material: Acrylic $\sigma_y = 12.59$ ksi.




$$\sigma_b = \frac{6(Nh - Fl)}{w^2 t} = \frac{6(173.5lb \times 4in - 41.8lb \times 2.6in)}{(0.5in)^2 \times 0.25in}$$

$$= 5.62ksi$$

$$FoS_b = \frac{\sigma_y}{\sigma_b} = \frac{12.59ksi}{5.62ksi} = \boxed{1.88}$$

$$\sigma_a = \frac{F}{wt} = \frac{41.8lb}{0.5in \times 0.25in} = 334.4psi$$

$$FoS_a = \frac{\sigma_y}{\sigma_a} = \frac{12.59ksi}{334.4psi} = \boxed{31.7}$$

$\Rightarrow$ **FoS = 1.88 for right rotary arm.**

Bumper

iv)

For each bumper,

$F = 8.2N = 36.5lb.$

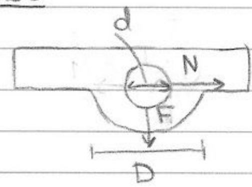
$$\sigma_a = \frac{F}{A} = \frac{36.5lb}{\frac{1}{3}\pi[(1.2in)^2 - (0.89in)^2]} = 53.8psi.$$

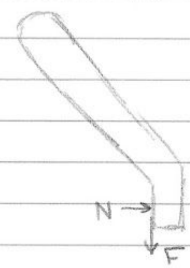
$\sigma_y = 9380psi.$

$$FoS = \frac{9380psi}{53.8psi} = 174.$$

Note: The E-shaped acrylic piece is used for lining the three fixed arms. In ideal situation, there should be no force exerted on the piece.

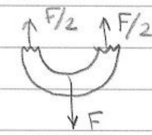
Base



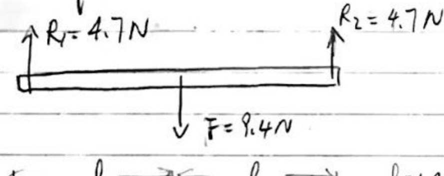

$$\sigma_c = \frac{\sqrt{N^2 + F^2}}{dt}$$

$$\sigma_a = \frac{F}{(D-d)t}$$



Shafts

for each shaft:



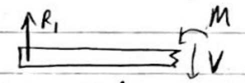

$d = \frac{1}{4}in$ ○

$l = 1.875 in$

$\Sigma F = R_1 + R_2 = 9.4N$

$\Sigma M_1 = 0: \quad 2R_2 = F$

$\Rightarrow R_1 = R_2 = \frac{1}{2}F = 4.7N$




$M_{max} = R_1 l$

$\sigma_b = \frac{M_{max}\frac{d}{2}}{\frac{\pi}{4}(\frac{d}{2})^4} = \frac{32 M_{max}}{\pi d^3} = \frac{32 \cdot 4.7N \times 1.875in}{\pi(\frac{1}{4}in)^3}$

$= \frac{32 \times 4.7N \cdot 0.047625m}{\pi(0.00635m)^3}$

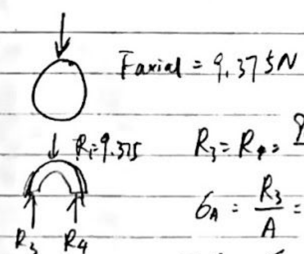
$= 8.9 \times 10^6 \, N/m^2$

$= \boxed{1287.7 \, psi}$

1045 Carbon Steel: $\sigma_y = 45ksi$

$FoS = \frac{45ksi}{1287.7psi} = \boxed{35}$

Bearing




$R_3 = R_4 = \frac{9.375N}{2} = 4.69N$

$\sigma_A = \frac{R_3}{A} = \frac{4.69N}{0.1875in \times 0.065in} = \frac{1.054lbf}{0.012188in^2} = \boxed{86.1538 \, psi}$

$FoS = \frac{\sigma_y}{\sigma_A} = \frac{45ksi}{86.2psi} = \boxed{522}$

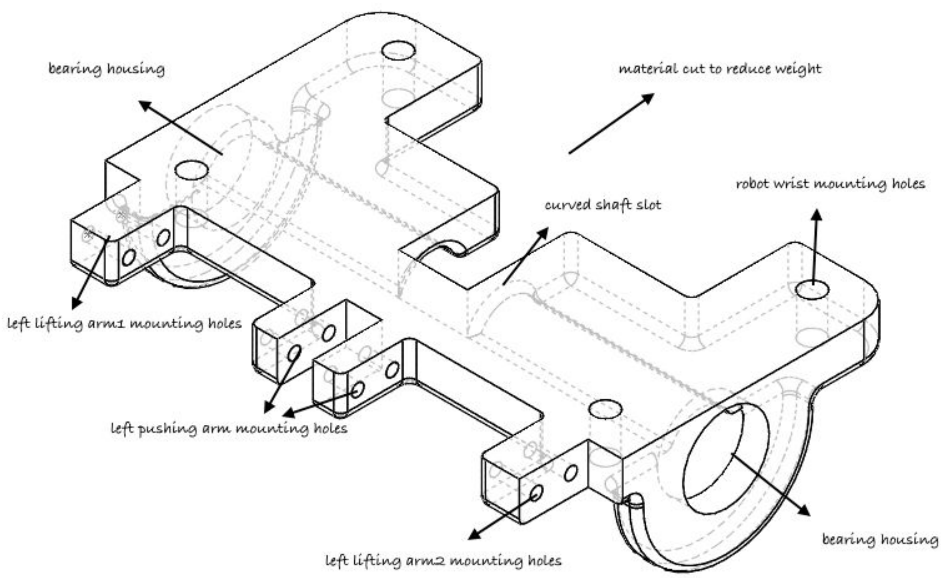
V. Material Selections

Base Mount, Left Arm - For the base of the part that mounts to the test stand, we decided on using the FormLabs 2 3D printer resin, v2. We elected to go with this option because we wanted to have a part that was lightweight as easy to make with the complex shape we had designed. For our first iteration we had hand machined the aluminum base, but this version required a much more complex design. The part only undergoes a peak stress of 3.675*10^2 psi compression, which is below the yield strength of 9380 psi by a reasonable factor of safety.

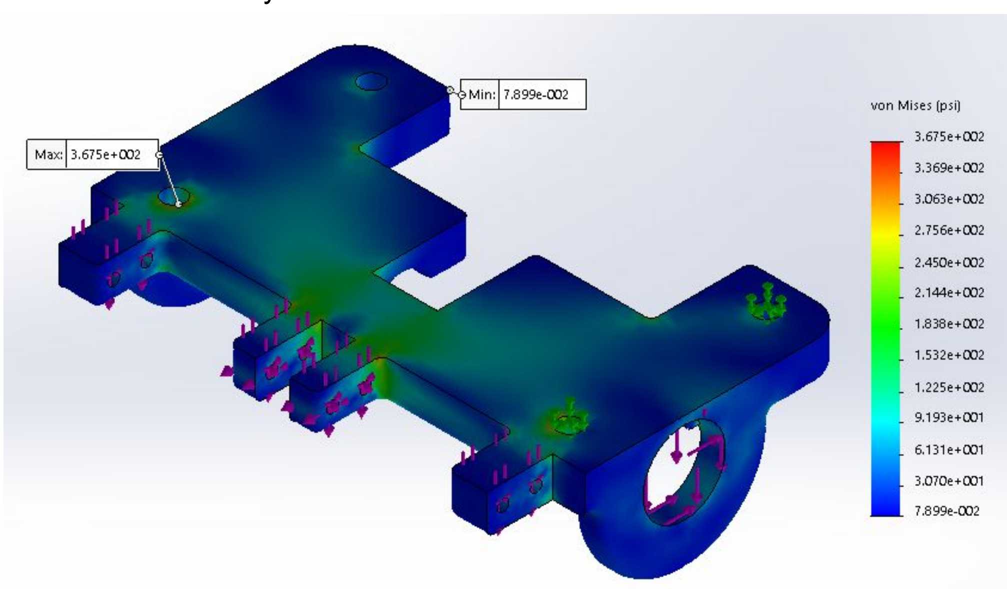
Right Arm, Support Arms - For the side support arms and the moving arm we decided to use ¼ inch acrylic. This was because we wanted a modularity to our gripper. Based on our preliminary test with arms shattering when the fidget spinner fell out, we decided that we need a material that could be easily manufactured into new arms. The ability to mass manufacture arms because acrylic is laser cut table was very important to our decision. In addition, the peak stress experienced during dynamic motion by the components made from this material is 3.660*10^2 psi axial stress due to bending, which is significantly below the yield strength of 10.59 ksi. We chose to have such a high factor of safety here, however, to account for the peak forces experienced during the impulses that stop the right arm when it opens and closes.

VI. Detailed Model and Analysis of Final Design

1. Base Plate
    a. Isometric Screenshot

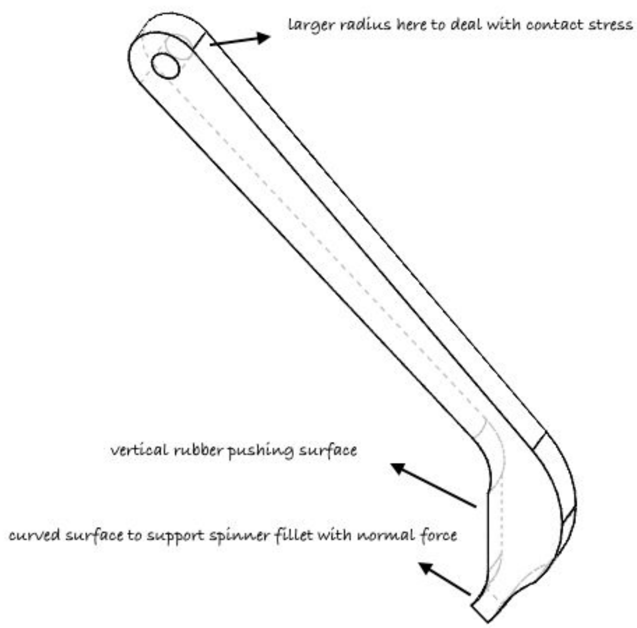



    b. Static Stress Analysis

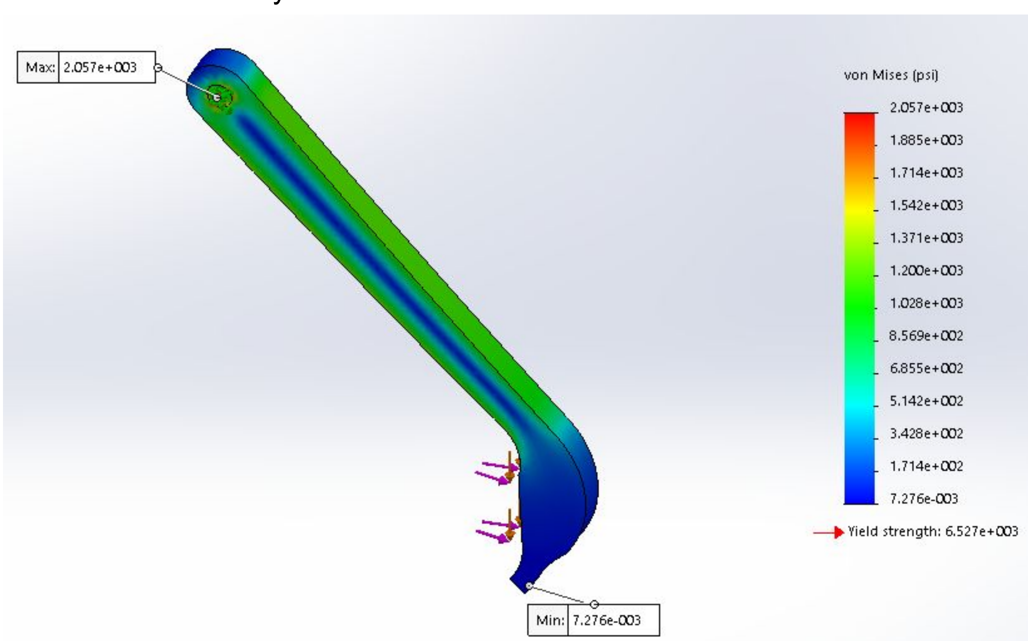



    c. Material and Yield Strength
        i. Material: Photopolymer Resin(Clear)
        ii. Yield Strength = 9380 psi
    d. Component Mass = 34.20 g
    e. Component Cost and Manufacturer
        i. Cost: $9.01   Manufacturer: Mitchell Riek

2. Right Arm
    a. Isometric Screenshot

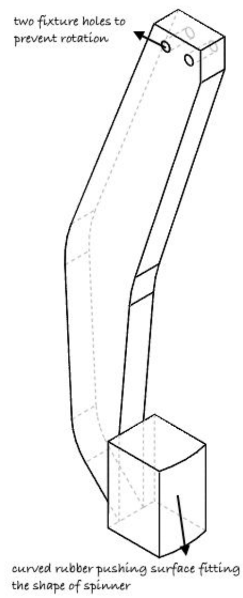



    b. Static Stress Analysis

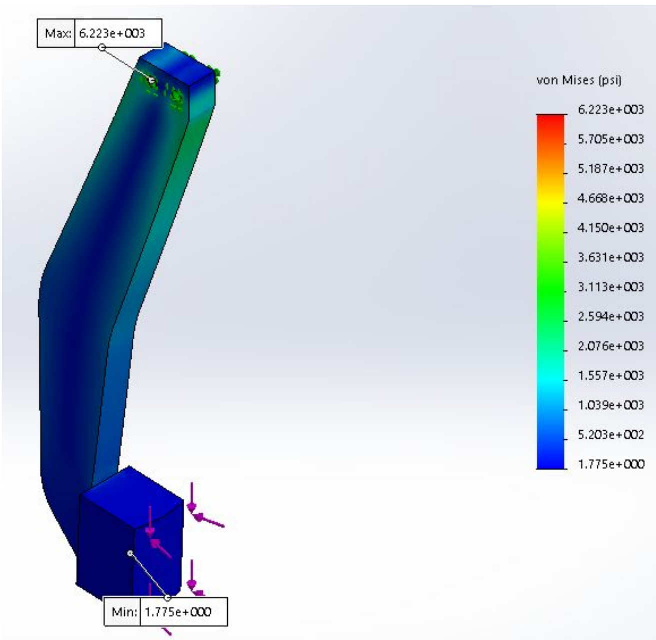



    c. Material and Yield Strength
        i. Material: Acrylic(Medium-high impact)
        ii. Yield Strength = 10.59 ksi
    d. Component Mass = 20.13 g
    e. Component Cost and Manufacturer
        i. Cost: $0.25     Manufacturer: Victoria Britcher

3. Left Arm
   a. Isometric Screenshot

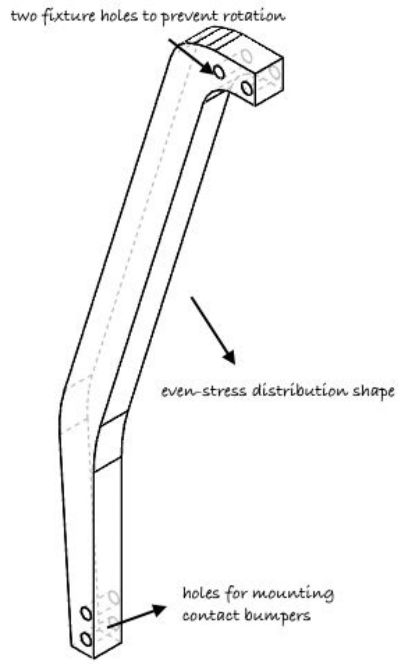



   b. Static Stress Analysis

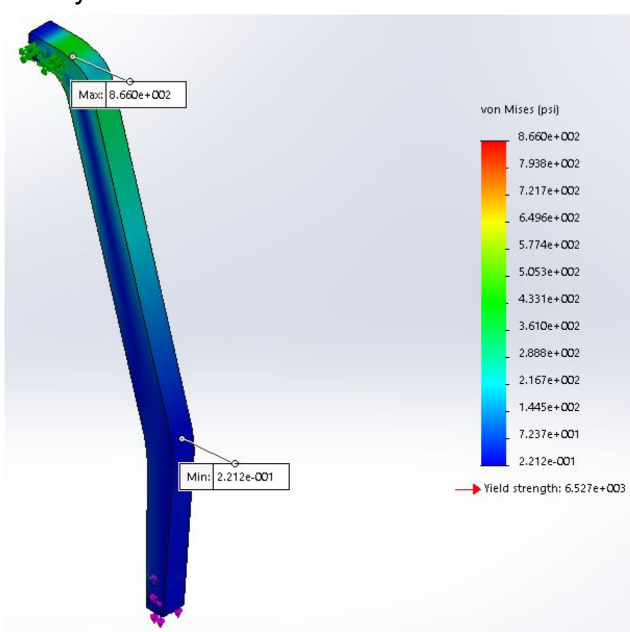



   c. Material and Yield Strength
      i. Material: Photopolymer Resin(Clear)
      ii. Yield Strength = 9380 psi
   d. Component Mass = 18.98 g
   e. Component Cost and Manufacturer
      i. Cost: $5.00 Manufacturer: Mitchell Riek

4. Support Arm
    a. Isometric Screenshot

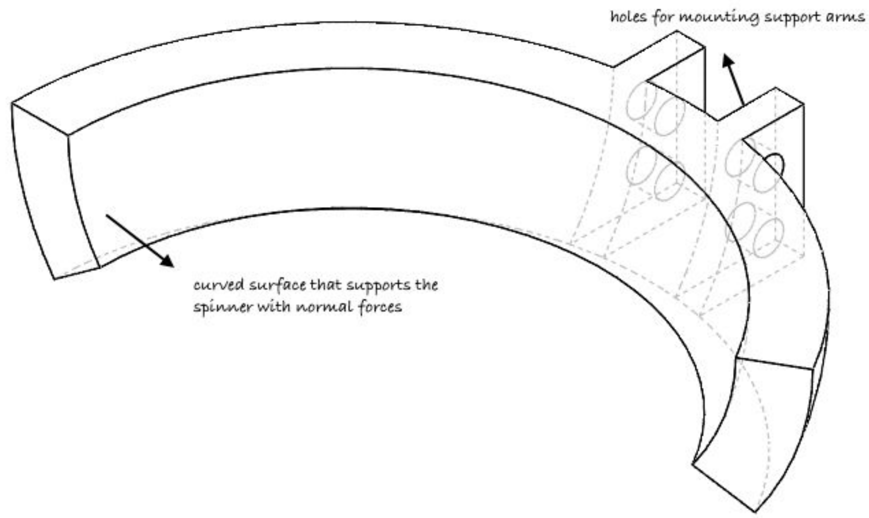



    b. Static Stress Analysis

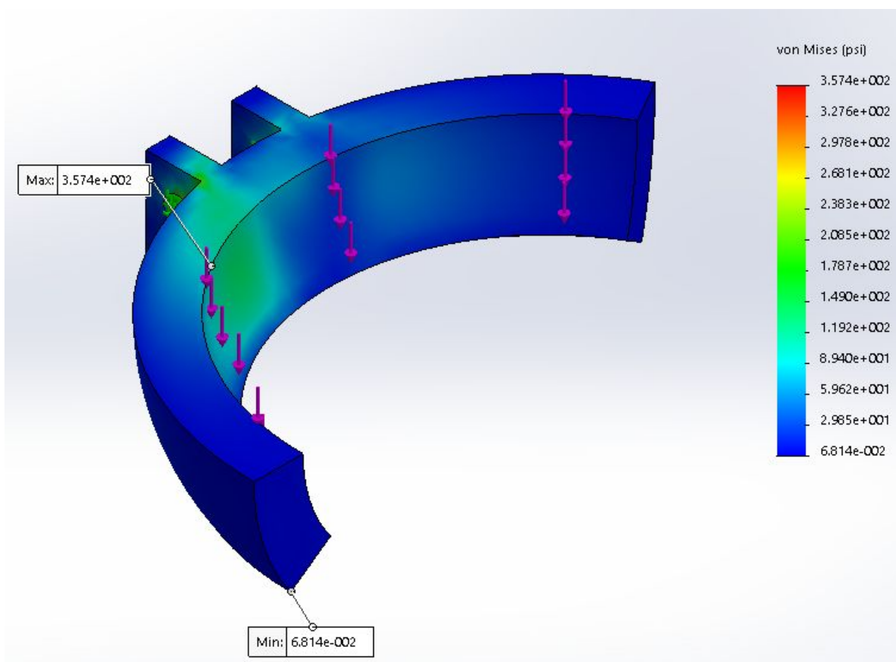



    c. Material and Yield Strength
        i. Material: Acrylic(Medium-high impact)
        ii. Yield Strength = 10.59 ksi
    d. Component Mass = 8.72 g
    e. Component Cost and Manufacturer
        i. Cost: \$0.11 (x2)    Manufacturer: Victoria Britcher & Yufan Wang

5. Contact Bumper
    a. Isometric Screenshot




    b. Static Stress Analysis




    c. Material and Yield Strength
        i. Material: Photopolymer Resin(Clear)
        ii. Yield Strength = 9380 psi
    d. Component Mass = 5.14 g
    e. Component Cost and Manufacturer
        i. Cost: $1.35 (x2)          Manufacturer: Terence Huang & Oliver Zhang

## VII. Catalog Component Selection

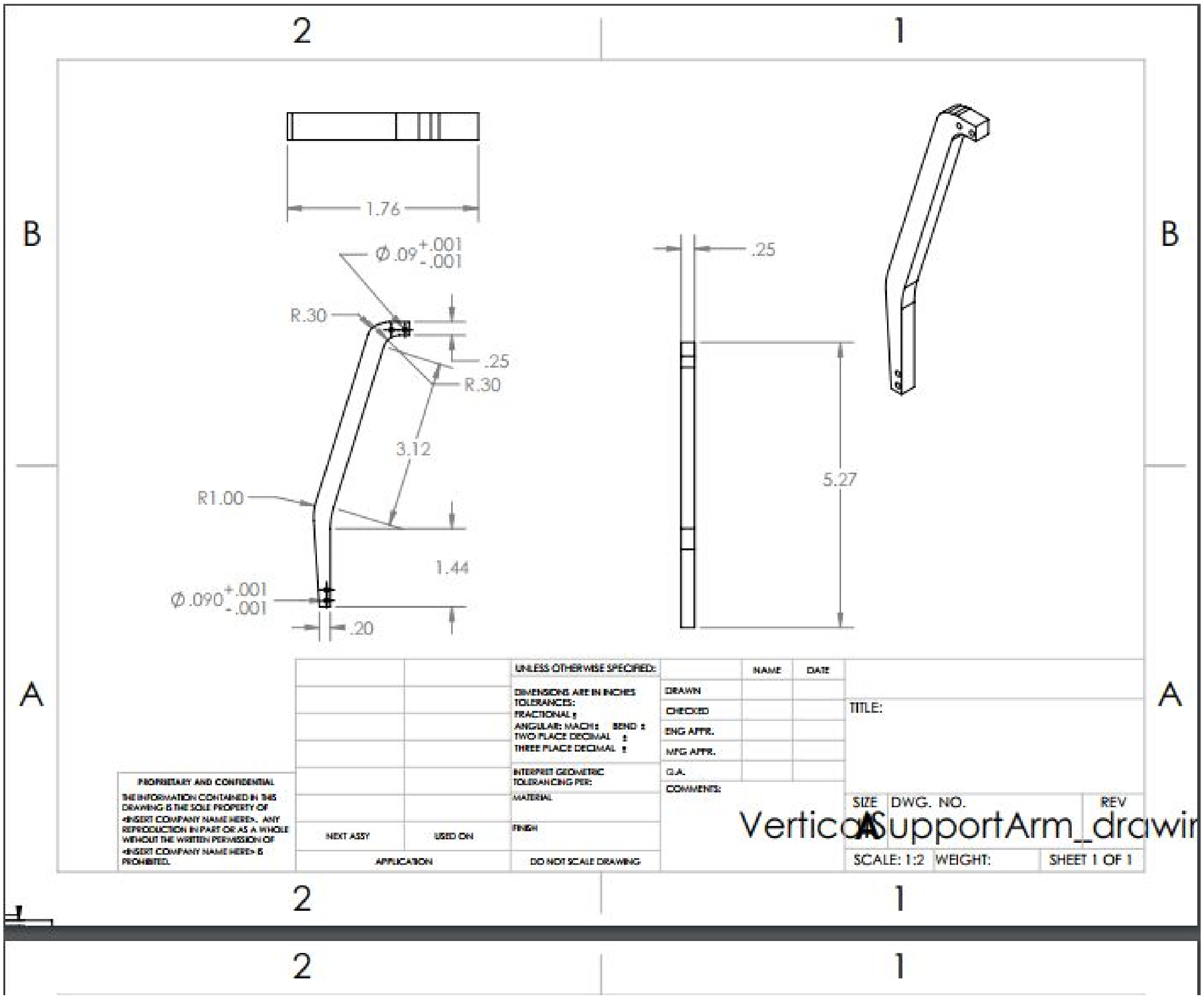
Small and Large gears - We chose acetal gears to reduce weight because we did not need the extra strength of a metal gear at this location. The sizes were chosen to match the shaft diameters of our shaft and the drive shaft, as well at satisfying the calculated gear ratio. We chose to purchase catalog components over making acrylic gears because precision was very important.

Bearings - We selected steel ball bearings to hold the shaft in the mount because minimizing friction forces on the rotation was the most important feature. This was done to maximize the applied torque, by reducing losses to friction. Weight was not as important for these parts, as we used lightweight materials in other locations to compensate.

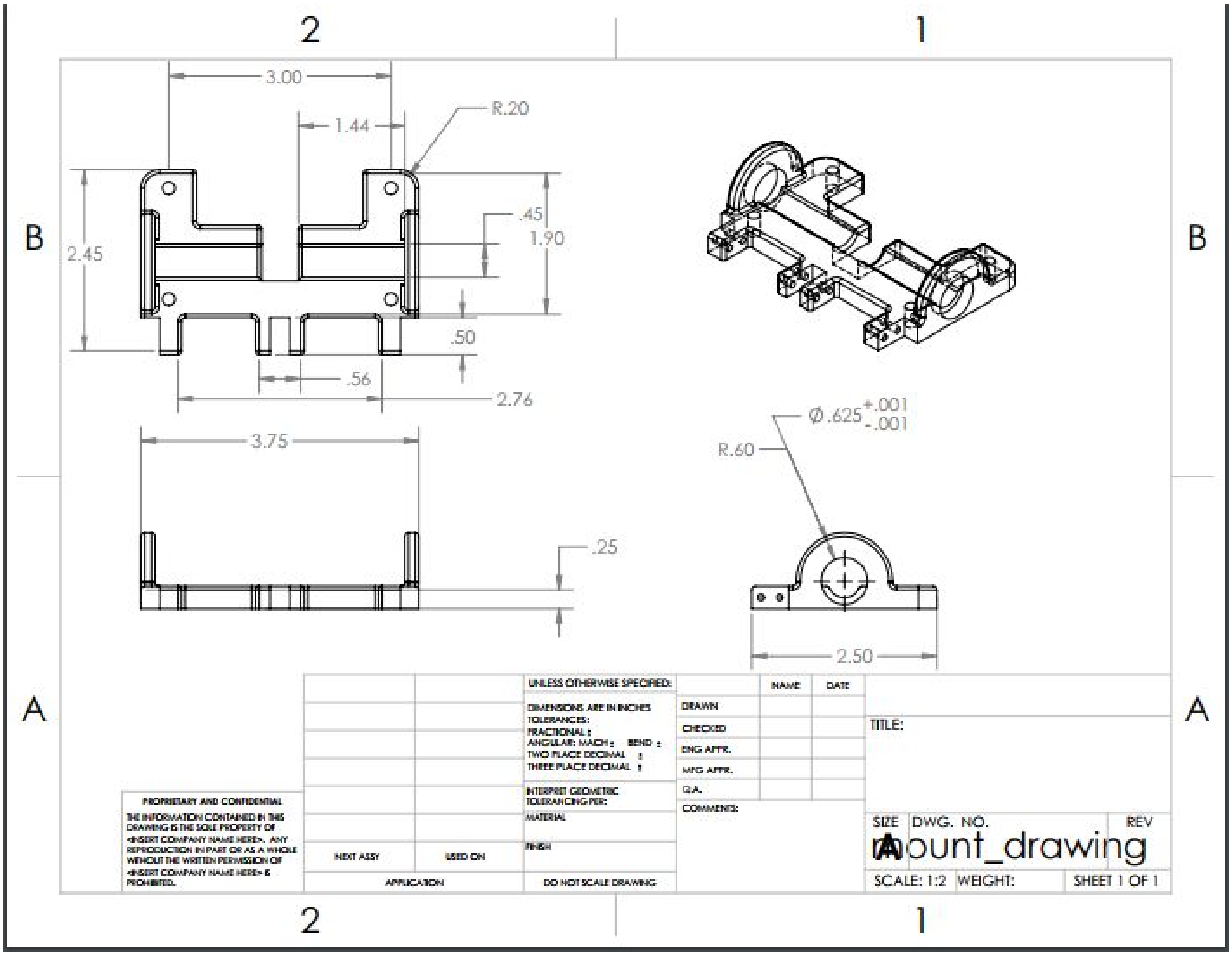
Shaft - We decided to purchase a catalog shaft because precision was the most important feature of the part. We decided on steel for the material because the majority of the force is supported by the shaft. The D shaft feature was decided on, because we planned to use set screws on the gears and the arms to affix them to the shaft and transfer the rotational motion.

VIII. Engineering Drawings

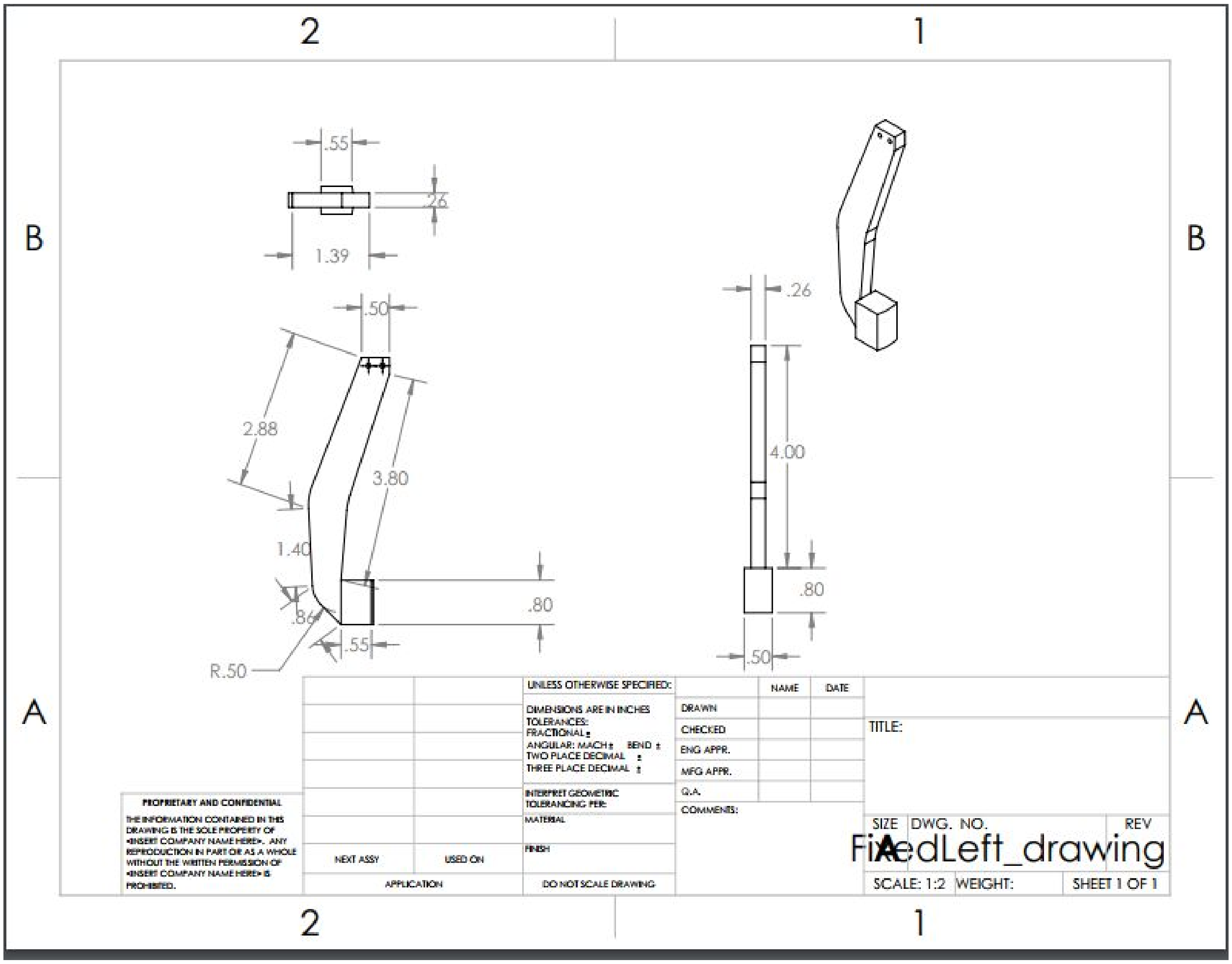
A) Fixed Left Lifting Arm



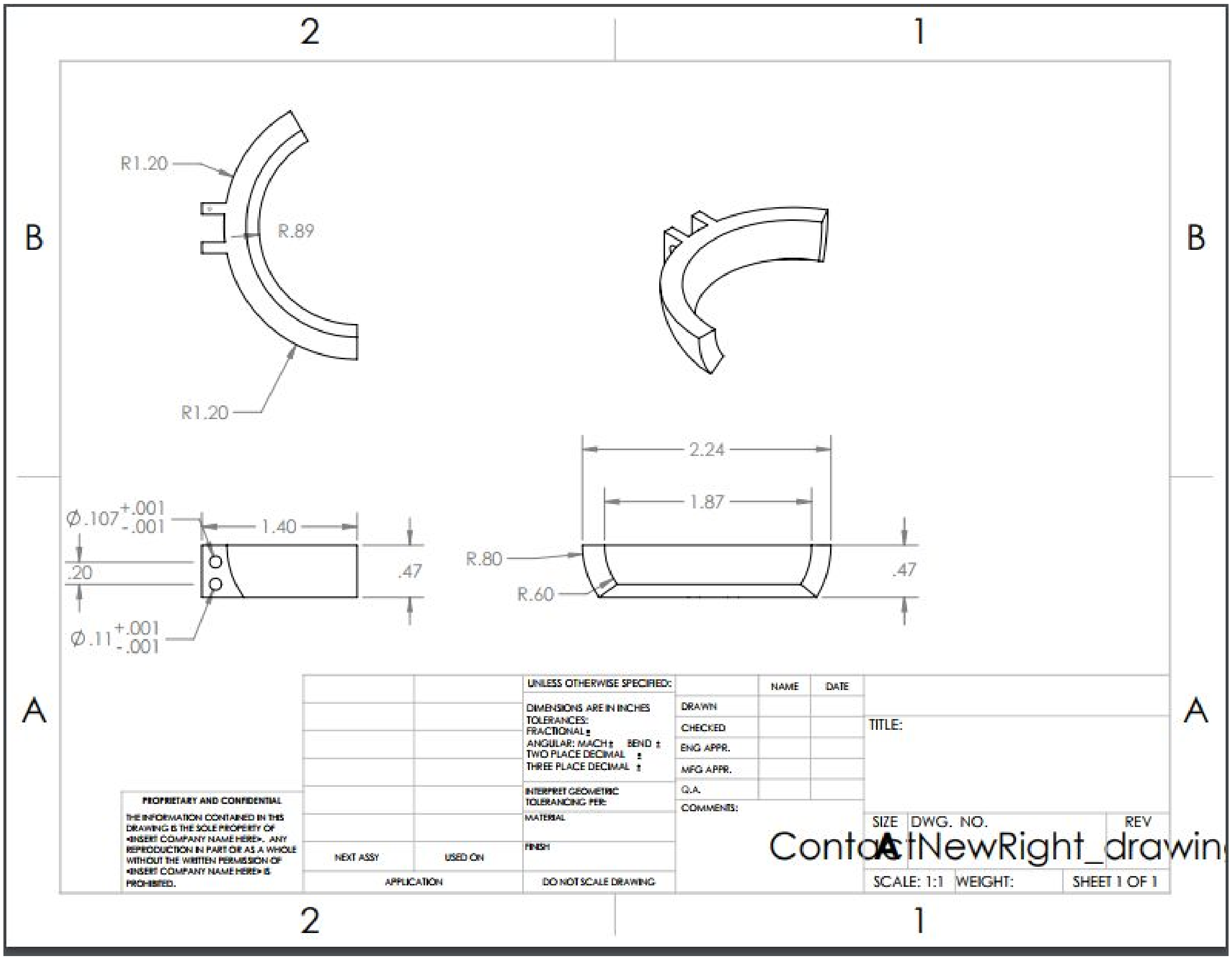
B) Mount


3.00
1.44
R.20
.45
1.90
2.45
.50
.56
2.76
3.75
.25
Ø.625 +.001 -.001
R.60
2.50
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
SIZE
DWG. NO.
REV
A
mount_drawing
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

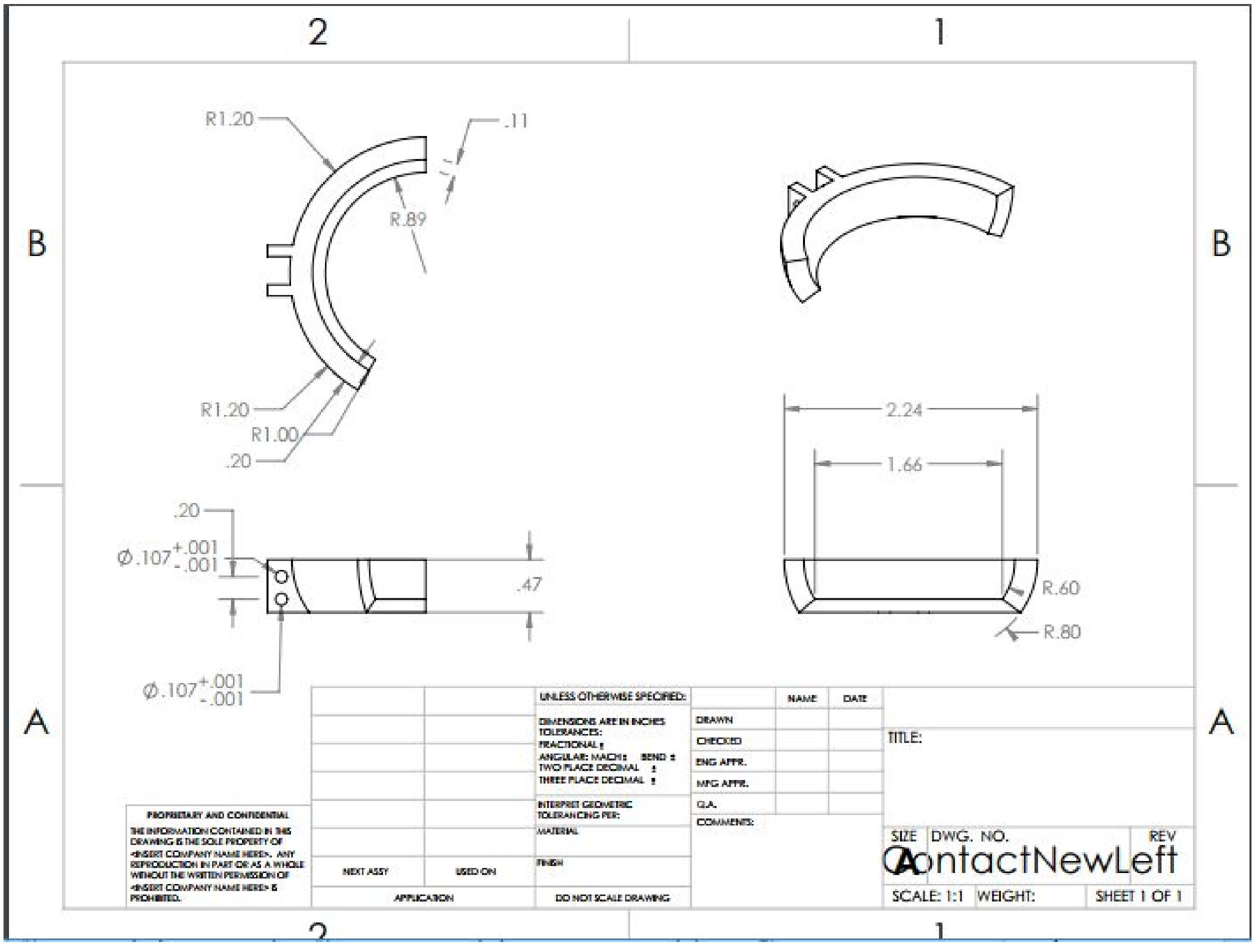
C) Left Fixed Pushing Arm



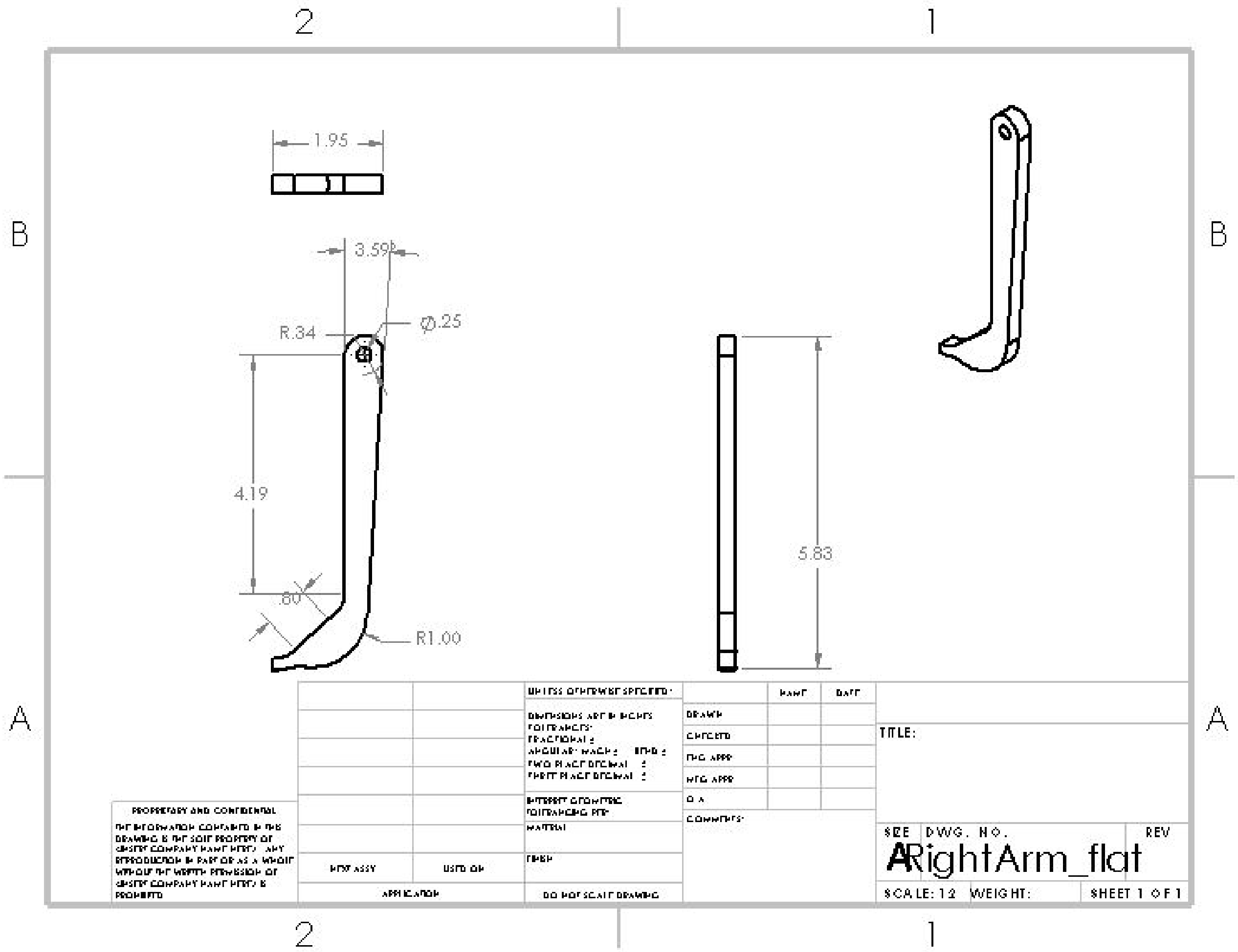
D) Contact Bumper(Right)



E) Contact Bumper (Left)



F) Right Rotary Arm



F) Line-up Tool for Left Arms