DUKE UNIVERSITY, PRATT SCHOOL OF ENGINEERING

ME321 - Group Project 2

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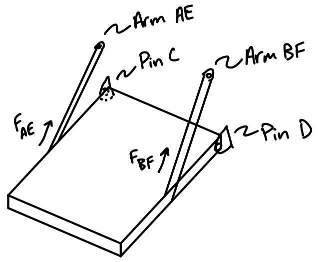
Date Performed . . . . February 1, 2024

Professor . . . . Dr. Santillan

1.



Both arms BF and AE will experience compressive stress and no other stresses. The pins at C and D will experience direct shear from the platform and wall. The pins at A and B will have direct shear from the arms and the wall. The pins at E and F will experience direct shear from the arms and platform. The platform will have compressive and tensile stress on the top and bottom respectively as well as bending stress, direct shear stress, torsion, and transverse shear stress.

There will be stress concentrations at the transverse holes for the pins in the support arms, at the transverse holes in the wall connections for the pins, and at the through holes in the platform for the bolts to secure the pulley.

The pins are most likely to have the maximum stress due to loading because of their relatively small cross sectional areas compared to other components. The pins would fail at the location where the two parts they are connecting are adjacent, i.e. where the arm is flush against the wall or platform. The forces change direction at this location, which would cause a sharp change in shear and stress build up. The platform would be most likely to fail at the pin locations due to stress concentrations or at the midpoint between points E and F on the bottom side of the platform because the bending stress is maximized there. For the arms, the key locations would be the pin holes because of stress concentration.

2.

2a.

Arms BF:

Compressive stress in BF: $\sigma_o = \frac{F_{BE}}{A}$

Pins:

Direct shear stress in Pin B: $\tau_{max} = \overbrace{\frac{4}{3}\frac{V}{A}}^{\text{Max shear for a circular cross section}}$

where $V = \sqrt{\underbrace{R_x^2}_{\text{Force in x-direction}} + \underbrace{R_z^2}_{\text{Force in z-direction}}}$

Platform:

Max bending stress: $\sigma_B = \frac{M_{max}\, y_{max}}{I}$

where $y_{max} = -\frac{\overbrace{h}^{\text{Platform height}}}{2}$ (Bottom), M_{max} = Moment at support arms

Direct shear stress in pin holes: $\tau = \frac{V}{A}$

where $V = \sqrt{R_{x_i}^2 + R_{z_i}^2}$

for each different pin

Torsion in platform: $T = (\underbrace{F_1}_{\text{Tight tension}} - \underbrace{F_2}_{\text{Loose tension}})\underbrace{R}_{\text{Pulley radius}}$

Shear in platform:

$$\tau_{max} = \underbrace{\frac{3}{2}\frac{V}{A}}_{\text{Rectangular cross-section}}$$

Maximum shear could be due to pulley or support arms, numeric analysis required

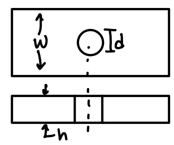
Transverse shear $= \frac{VQ}{Ib}$

Will vary heavily in I, Q, and b based on weight reduction techniques. Shear will be based on pulley and support arm forces.

2b.

For support arms:

Stress concentration factor is a function of $\frac{d}{w}$ — d: Hole diameter, w: Bar width



Leave as K_t, so $\sigma_{max} = K_{t_1}\frac{F_{BF}}{A}$ — Arm BF more likely to fail first

where $A = h(w-d)$

For platform:

Again, stress concentration factor is a function of $\frac{d}{w}$

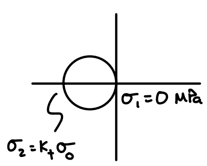
This time we have shear stress, so $\sigma = K_{t_2}\frac{VQ}{Ib}$

These concentrations arise at pin hole locations with support arms and wall.

c.

For support arms:

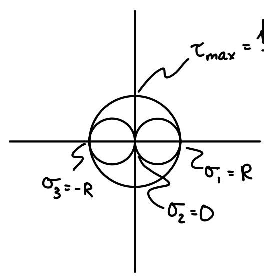
Stress is purely axial



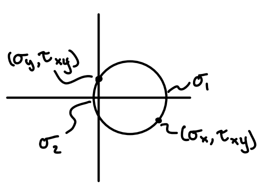
$\tau_{max} = \frac{K_t \sigma_o}{2}$

For pins:

$\tau_{max} = \frac{\sqrt{R_x^2 + R_z^2}}{A} = R$



For platform:



$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

$\tau_{max} = R$

$\sigma_1 = \frac{\sigma_x - \sigma_y}{2} + R$

$\sigma_2 = \frac{\sigma_x - \sigma_y}{2} - R$

d.

Ductile materials:

From Max Shear Stress Theory:

$$\tau_{max} = \frac{\frac{1}{2} S_y}{n}$$

$$n = \frac{S_y}{2\tau_{max}}$$

Brittle Materials:

$$\sigma_A < \frac{S_{ut}}{n}$$

$$\frac{\sigma_A}{S_{ut}} - \frac{\sigma_B}{S_{uc}} < \frac{1}{n}$$

$$\sigma_B < -\frac{S_{uc}}{n}$$

Distortion Energy Theory:

$$\sigma' = \frac{1}{\sqrt{2}}\left[(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_x-\sigma_z)^2+6(\tau_{xy}^2+\tau_{yz}^2+\tau_{xz}^2)\right]^{1/2}$$

$$n = \frac{S_y}{\sigma'}$$

Since Distortion Energy theorem is more conservative, we will use that safety factor.

e.

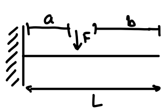
Based on the Euler buckling formula (slender arms),

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

f. For maximum deflection, use superposition for pump force and arm forces

From table A-9:

2. Cantilever with intermediate load:



$$y_{AB} = \frac{Fx^2}{6EI}(x-3a)$$

$$y_{BC} = \frac{Fa^2}{6EI}(a-3x)$$

$$y_{max} = \frac{Fa^2}{6EI}(a-3L)$$

For platform:

$$y_{max} = \frac{F_1 a_1^2}{6EI}(a_1-3L) - \frac{F_2 a_2^2}{6EI}(a_2-3L)$$

Where F_1, a_1 belong to the pulley and F_2, a_2 belong to the support arms

Dimensions and Approximate K Values

Component	Dimension	Loading	d/w Ratio	Approximate K
Support Arm (Bar with Hole)	W = 1 in, d = 0.25 in, l = 22 in	Axial (Compression)	0.25	2.2
Pin (Clevis Pin)	D = 0.25 in, l = 1 in	Pure Shear	N/A	1.0
Platform (Large Plate with Small Holes)	w = 12 in, d = 0.25 in, l = 18 in	Shear Around Hole	0.02	1.9

* Aluminum assumed for all materials

Loads: $T_{shaft} = \frac{Power}{\omega} = \frac{2600W}{2\pi \cdot (1800/60)\ \text{rad/s}} = 13.85\ N\cdot m = 10.2\ ft\cdot lb$

$\Delta F_{belt} = \frac{T_{shaft}}{r} = \frac{13.85}{0.127} = 109N = 24.5\ lbs$

$F_{horiz} = \frac{13.85}{0.471} = 29.4\ N = 6.6\ lbs$

Arm Calculations: 1 in x .25 in x 22 in , $K_t = 2.2$

$\sigma_{nom} = \frac{F_{arm}}{A}$ Assuming $F_{arm} \approx 25$ lbs, $\sigma_{nom} = \frac{25\ lbs}{0.25\ in^2} = 100\ psi$

$\sigma_{max} = K_t \sigma_{nom} = 2.2 \cdot 100\ psi = 220\ psi$

assuming Aluminum construction...

$FOS = \frac{\sigma_y}{\sigma_{max}} = \frac{40{,}000}{220\ psi} = 182 \gg 1.5$ ✓

Buckling: $I = \frac{(.25 in)^3(1.0 in)}{12} = 0.001302\ in^4$

again assuming aluminum $\Rightarrow E = 10 \cdot 10^6\ psi$

$P_{cr} = \frac{\pi^2 EI}{L^2} = \frac{(9.8696)(10 \cdot 10^6)(0.001302)}{(22)^2} = 266\ lb$ (critical load)

$FOS_{buckling} = \frac{266}{25} = 10.6 > 1.5$ ✓

Pin Calculations:

Shear Stress: $A = \frac{\pi d^2}{4} = \frac{\pi \cdot 0.25^2}{4} = 0.049\,in^2$

again assuming $\approx 25\,lb$ shear $\rightarrow \tau_{pin} = \frac{25\,lb}{0.049\,in^2} = 510\,psi$

$\tau_{max} \leq \frac{S_y}{\sqrt{3}} \approx \frac{40{,}000}{\sqrt{3}} = 23{,}000\,psi$

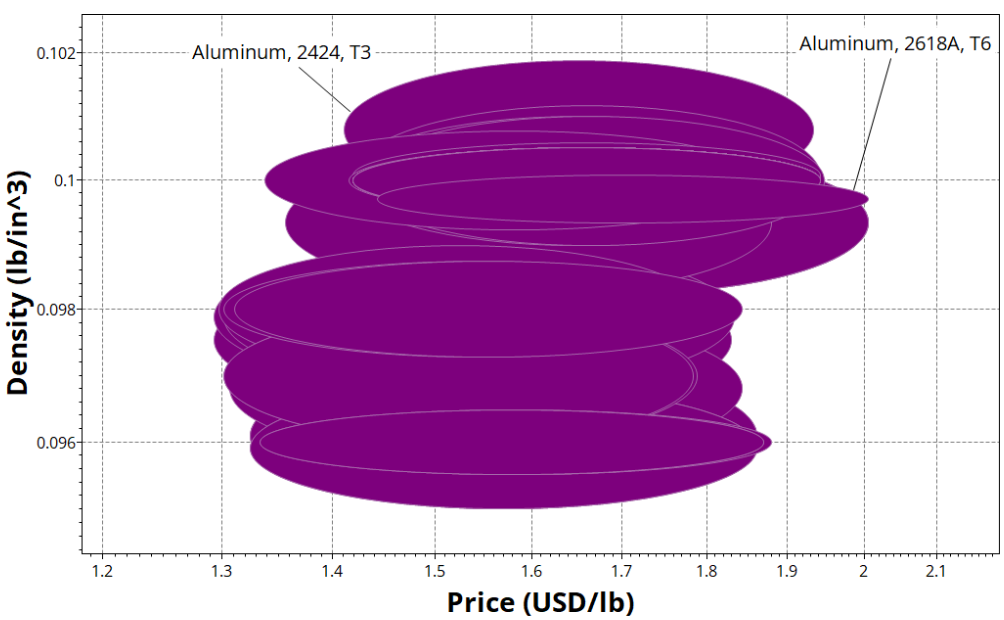
$FOS = \frac{23000}{510} = 45 \gg 1.5$ ✓

Platform Deflection:

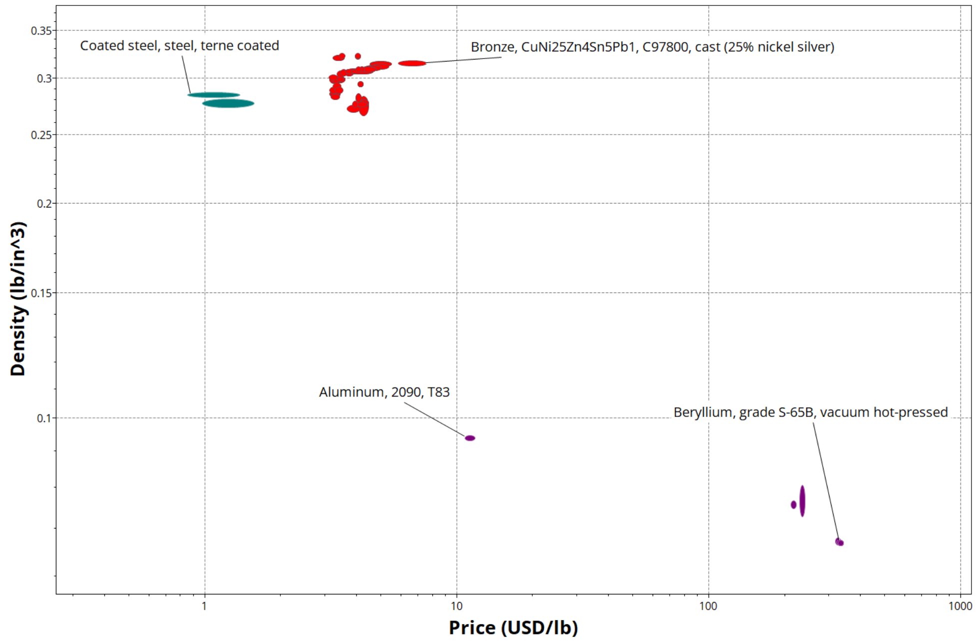
$I = \frac{bh^3}{12} = \frac{12 \cdot 0.5^3}{12} = \frac{12 \cdot .125}{12} = 0.125\,in^4$

$\delta_{max} = \frac{FL^3}{3EI}$ *Assume material is steel*
$E = 29 \cdot 10^6\,psi$

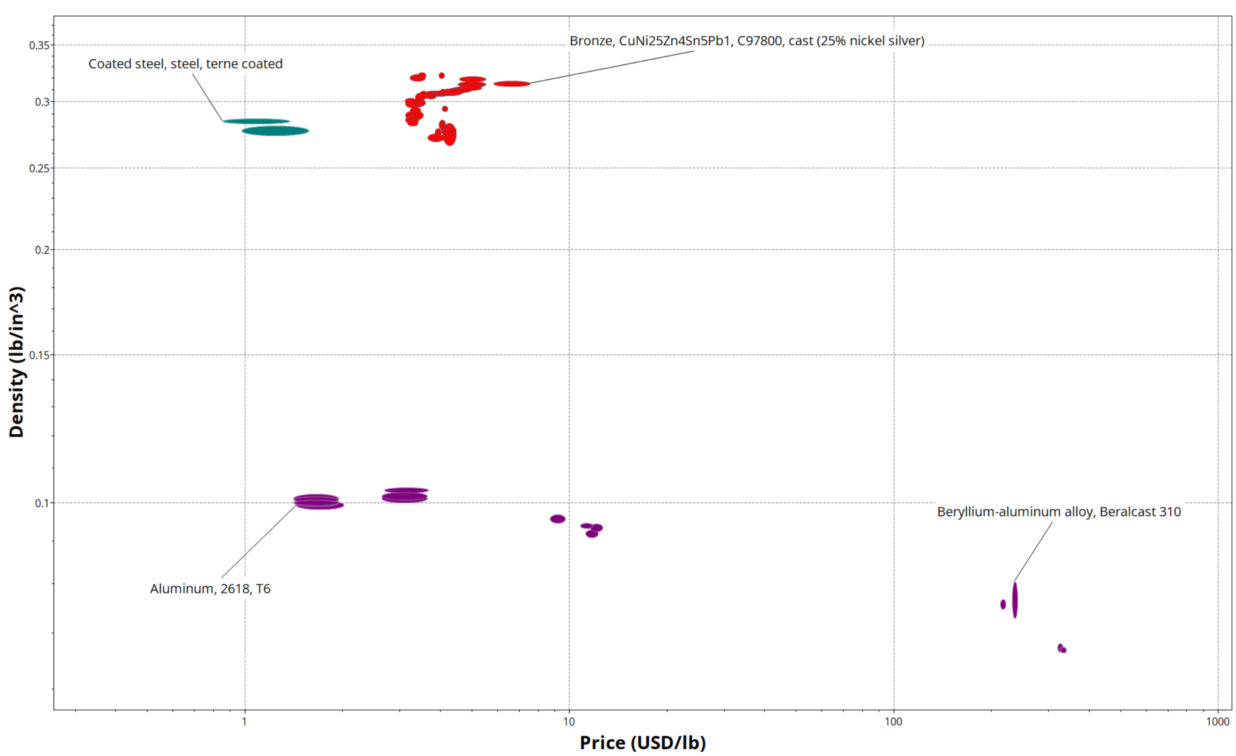
$\delta_{max} = \frac{37 \cdot 18^3}{3(29 \cdot 10^6) \cdot .125} = 0.0198\,in = .5\,mm$ which is under 1mm limit ✓



Density vs. Price for Support Arm Materials



Density vs. Price for Pin Materials



Density vs. Price for Platform Materials

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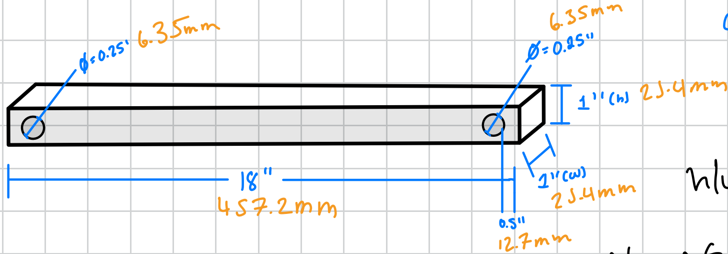
3.)

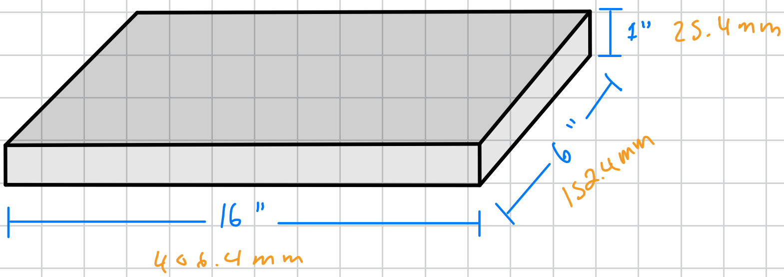
Arms



h/w=

d/w=0.5

Platform

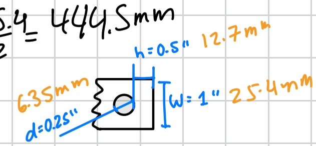


4.)

$h = L - w/2 = 457.2 - \frac{25.4}{2} = 444.5\text{mm}$

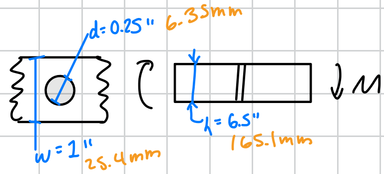
$h/w = \frac{444.5}{25.4} = 17.5\text{mm}$

$d/w = \frac{6.35}{25.4} = 0.25\text{ mm}$



From table A-15-12

$\boxed{\rightarrow K_t \approx 4}$



$d/w = 6.35/25.4 = 0.25\text{ mm}$

$d/h = 6.35/152.4 = 0.0417\text{ mm}$

From Table A-15-2

$\boxed{K_t = 2.4}$

5.)

Factor of Safety

Arm BF

$A_{BF} = (25.4 - 6.35)(25.4) = 483.87$

$\sigma_{axial} = \frac{R_F}{A_{BF}} = \frac{-246.59}{483.87} = -0.509\text{ MPa}$

$\sigma_{xx_{BF}} = K\sigma_{nom_{BF}} = 4(0.509) = -2.04\text{ MPa}$

$C = \frac{\sigma_{xx}}{2} = \frac{-2.04}{2} = -1.02\text{ MPa}$

$\tau_{xy} = 0$

$R = \sqrt{(0.5\times(\sigma_{xx_{BF}} - \cancel{\sigma_{yy_{BF}}}^{0}))^2 + \cancel{\tau_{xy_{BF}}^2}^{0}} = \sqrt{(0.5(2.04))^2} = 2.08\text{ MPa}$

$\sigma_1 = C + R = 1.06\text{ MPa}$

$\sigma_2 = C - R = -3.1\text{ MPa}$

$\sigma_{von_{BF}} = \sqrt{\sigma_{1_{BF}}^2 + \sigma_{2_{BF}}^2 - \sigma_{1_{BF}}\sigma_{2_{BF}}}$

$= \sqrt{1.06^2 + 3.1^2 - (3.1)(1.06)}$

$= 2.03\text{ MPa}$

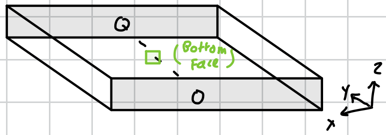
$\rightarrow n_{BF} = \frac{\sigma_Y}{\sigma_{von_{BF}}} = \boxed{\frac{\sigma_Y}{2.03}}$

Factor of Safety

Platform

Location 1:

Bottom face at center of width (y) at pin location (x)



Bending

$$\sigma_B = \frac{M_z}{I_y} =$$

$$I_y = \frac{Wt^3}{12} - \frac{Wd^3}{12}$$

$$= \frac{W}{12}(t^3 - d^3)$$

$$= \frac{152.4}{12}(25.4^3 - 6.35^3)$$

$$= 204863.9\,mm^4$$

$$\sigma_{B_0} = \frac{Mc}{R} = \frac{84058\,Nmm\,(12.7)}{204863.9}$$

$$\sigma_{B_0} = 5.21\,MPa$$

$$\sigma_B = K_t \sigma_{B,0} = (5.21)(2.4)$$

$$\sigma_B = 12.51\,MPa$$

Axial

$$A = (W-d)t = (25.4 - 6.35)(152.4) = 2903.22\,mm^2$$

$$\sigma_D = \frac{R_x^C + R_x^D}{A} = \frac{174.37 + 143.71}{2903.22} = 0.109\,MPa$$

$$\sigma_{ax} = K_t \sigma_D = (2.4)(0.109) = 0.26\ MPa.$$

Torsion

$$\tau_{max} = \frac{M_x^G}{\alpha w t^2} = \frac{13.85\,Nm}{0.299(152.4)(25.4)^2} = 0.47\,MPa$$

$$b/c = \frac{152.4}{25.4} = 6 \rightarrow \alpha = 0.299$$

Transverse Shear $= 0$

Total

$$\sigma_x = \sigma_b + \sigma_{ax} = 12.51 + 0.26 = 12.77$$

$$\sigma_y = 0$$

$$C = \frac{\sigma_x + \sigma_y}{2} = 6.385$$

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \sqrt{\left(\frac{12.77}{2}\right)^2 + 0.47^2} = 6.40$$

$$\sigma_1 = C + R = 12.785\,MPa$$

$$\sigma_2 = C - R = -0.015$$

$$\tau_{max} = 6.4$$

$$\sigma_{von} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2}$$

$$\sigma_{von} = \sqrt{12.785^2 + 0.015^2 - 12.785(0.015)}$$

$$= 12.75\,MPa$$

$$\rightarrow n = \frac{\sigma_Y}{\sigma_{von}} = \boxed{\frac{\sigma_Y}{12.75}}$$

Made with Goodnotes

Location 2

Cross section where pin hole c/o lies.

Bending

None

Torsion

Countered by arms (none)

axial

For $(0,0,\pm d/2)$

$$\sigma_0 = \frac{F}{A} = \frac{R_{x^c}+R_{x^p}}{(w-d)t}$$

$$= \frac{174.37+143.71}{2903.22} = 0.109 \text{ MPa}$$

$$d/w = \frac{6.35}{25.4} = 0.25,\ \frac{h}{w} = \frac{12.7}{25.4} = 0.5;$$

$$K_t \approx 3.8$$

$$\sigma_{ax} = K_t \sigma_0 = 3.8(0.109)$$

$$\sigma_{ax} = 0.414 \text{ MPa}$$

For $(\pm d/2, 0, 0)$

$$A = l \times w = 152.4 \times 25.4 = 3870.96 \text{ mm}^2$$

$$\sigma_{ax} = \frac{F}{A} = \frac{174.37+143.71}{3870.96} = 0.082 \text{ MPa}$$

Total For $(0,0,\pm d/2)$

$$\sigma_x = 0.082 \text{ MPa}$$

$$r = \sqrt{\left(\frac{0.082}{2}\right)^2 + (0.148)^2}$$

$$r = 0.154$$

$$c = 0.041$$

$$\sigma_1 = c+r = 0.195 \text{ MPa}$$

$$\sigma_2 = c-r = 0.113 \text{ MPa}$$

$$\sigma_{von} = \sqrt{0.195^2+0.113^2-(0.195)(0.113)}$$

$$\sigma_{von} = 0.170$$

$$\boxed{n = \frac{\sigma_y}{0.170}}$$

Transverse For $(0,0,\pm d/2)$

$$\tau = VQ/Ib$$

$$Q = \frac{w}{2}(c^2 - y_1^2) = \frac{w}{2}\left(\left(\frac{d+t}{4}\right)^2 - \left(\frac{d}{2}\right)^2\right) = 21685.9 \text{ mm}^2$$

$$I = \frac{w}{12}(t^3 - d^3) = 204863.9 \text{ mm}^4$$

$$\tau = \frac{318.08(21685.9)}{204863.9(152.4)} = 0.22 \text{ MPa}$$

For $(\pm d/2, 0, 0)$

$$\tau_{max} = \frac{4V}{3A} = \frac{4(318.08)}{3(3870.96)} = 0.148 \text{ MPa}$$

Total

For $(\pm d/2, 0, 0)$:

$$\sigma_x = 0.414 \text{ MPa}$$

$$r = \sqrt{\left(\frac{0.414}{2}\right)^2 + (0.022)^2}$$

$$r = 0.21 \text{ MPa}$$

$$c = \frac{0.414}{2} = 0.207 \text{ MPa}$$

$$\sigma_1 = c+r = 0.417 \text{ MPa}$$

$$\sigma_2 = c-r = -0.003 \text{ MPa}$$

$$\sigma_{von} = \sqrt{\sigma_1^2+\sigma_2^2-\sigma_1\sigma_2}$$

$$\sigma_{von} = \sqrt{0.417^2+0.003^2-(0.003)(0.417)}$$

$$\sigma_{von} = 0.417 \text{ MPa}$$

$$\boxed{n = \frac{\sigma_y}{0.417}}$$

Location 3   At pin hole EF

Axial   None

Bending   None

Transverse

$$\tau_{max} = \frac{4V}{3A} = \frac{4V_0}{3(wt)} = \frac{4\,(318.08)}{3(152.4\times 25.4)}$$

$$\tau_{max} = 0.11\,MPa$$

Torsion

Torsion = 0.47 MPa

$$\tau_{max} = 0.47\times K = 0.47\times 3 = 1.41\,MPa$$

Total

$$\sigma_{vm} = \sqrt{3(\tau_{torsion}+\tau^2_{transverse})}$$

$$n = \frac{S_y}{\sigma_{vm}} = \frac{S_y}{3(\tau_{torsion}+\tau^2_{transverse})} = \frac{S_y}{3(0.11+0.47^2)}$$

We were initially opting to select aluminum 2424 or 2618 for use with the support arms, however, they are not readily available for purchase. We conducted our analysis using aluminum 2024, which was also recommended by Ansys and has similar performance characteristics with more availability.

The final selected dimensions for the arms are:
arm_w = 0.5”
arm_t = 0.145”
arm_l = 18”
This gives us a projected factor of safety just above 1.5 for both deflection and buckling when using 6061 Aluminum with minimal deflection.

```
Arm Calculations
hw 1.0 dw 0.5
Area: 0.02125
Sigma_D_arm: -11603.764705882353
Sigma_axial_arm: -29009.41176470588
Sigma_principal_arm_1: 0.0
Sigma_principal_arm_2: -29009.41176470588
sigma_von_arm: 29009.41176470588
Arm FOS: S_y / 29009.41176470588
Arm FOS: 1.5512206991645714
```

```
Arm Buckling Calculations
0.4921875
P_cr: 40.242118860547684
Buckling FOS: 1.6096847544219073
```

Given that the dimension of 0.085” is not commonly available, we will need to machine the face down to that size or elect to go with the next available size.

For the platform we selected the following dimensions and elected to go with aluminum 6061-T6 to alleviate costs and maintain lightweight characteristics:

p_w = 6”
p_t = 0.35”
p_l = 16”

This allows for very high deflection FOS of over 15 and satisfies the 1.5 FOS for all other categories. We could accomplish a more efficient design with increased weight reduction by reducing the thickness of the aluminum (and still meeting performance criteria), however, we need to be able to comfortably situate the 0.25” clevis pins into the side of the platform. Reducing the thickness more than this may not leave for a lot of room for the pin to rest on the side of the platform. We may attempt a workaround by constructing an alternative mounting point (angle bracket or hollow out the inside of the aluminum using a mill) in order to maximize the potential for weight reductions while maintaining optimal deflection characteristics.

```
Platform Case 1 Calculations
dh 0.041666666666666664 dw 0.7142857142857143
Moment of Inertia (y): 0.013624999999999995
Sigma_b_1: 9530.275229357801
Sigma_b: 20013.577981651382
Platform axial area: 0.5999999999999999
Sigma_D: 530.1333333333334
Sigma_axial: 1113.2800000000002
T_max: 10449.798648556412
Mohr's radius: 14858.813002376337
Sigma_von: 27819.759229062012
Platform Case 1 (bottom face along hole axis) FOS: S_y / 27819.759229062012
Platform Case 1 FOS: 1.6175553364599426
```

Appendix A: Code for calculating buckling, deflection, and factors of safety
import math

```
import math

#Arm FOS
print("Arm Calculations")
arm_w = 0.5
arm_t = 0.145
arm_l = 18
k_arm = 2.5
arm_E = 1.04*10**7
sy_arm = 45000

hw = 0.5/arm_w
dw = 0.25/arm_w

print(f"hw {hw} dw {dw}")

A_arm = (arm_w-0.25)*arm_t
print(f"Area: {A_arm}")
sigma_arm_axial = -246.58/A_arm #-1096N
print(f"Sigma_D_arm: {sigma_arm_axial}")
sigma_arm_xx = k_arm*sigma_arm_axial
print(f"Sigma_axial_arm: {sigma_arm_xx}")
```

```
mohrs_arm_center = sigma_arm_xx/2
mohrs_arm_radius = math.sqrt((0.5*sigma_arm_xx) ** 2)
sigma_arm_1 = mohrs_arm_center + mohrs_arm_radius
print(f"Sigma_principal_arm_1: {sigma_arm_1}")
sigma_arm_2 = mohrs_arm_center - mohrs_arm_radius
print(f"Sigma_principal_arm_2: {sigma_arm_2}")

sigma_von_arm = math.sqrt(sigma_arm_1 ** 2 + sigma_arm_2 ** 2 -
sigma_arm_1*sigma_arm_2)
print(f"sigma_von_arm: {sigma_von_arm}")
print(f"Arm FOS: S_y / {sigma_von_arm}")
sf = sy_arm / sigma_von_arm
print(f"Arm FOS: {sf}")
print()
print("-------------New Case------------")
print()
#Platform FOS Case 1
print("Platform Case 1 Calculations")
p_w = 6 #width (mm)
p_t = 0.35 #thickness (mm)
p_l = 16 #length (mm)
k_p = 2.1
alpha = 0.299
sy_p = 45000
E = 7*10**10
F1 = 25
F2 = 448.9435
a1 = 1.5
a2 = p_l - 3.75 - a1

dh = 0.25/p_w
dw = 0.25/p_t

print(f"dh {dh} dw {dw}")

I_y = p_w/12 * (p_t**3 - 0.25**3)
print(f"Moment of Inertia (y): {I_y}")

sigma_b_0 = 742*(p_t/2)/I_y

print(f"Sigma_b_1: {sigma_b_0}")
```

```
sigma_b = sigma_b_0 * k_p
print(f"Sigma_b: {sigma_b}")

#axial calculatios:
A_p = (p_t-0.25) * p_w
print(f"Platform axial area: {A_p}")

sigma_d = 318.08/A_p
print(f"Sigma_D: {sigma_d}")

sigma_axial = k_p * sigma_d
print(f"Sigma_axial: {sigma_axial}")

#torsion
t_max = 2296.5/(alpha * p_w * p_t**2)
print(f"T_max: {t_max}")

#total
sigma_x = sigma_b + sigma_axial
c = sigma_x / 2
r = math.sqrt((sigma_x/2)**2+t_max ** 2)
print(f"Mohr's radius: {r}")
sigma1 = c+r
sigma2 = c-r

sigma_von = math.sqrt(sigma1**2 + sigma2**2 -sigma1*sigma2)
print(f"Sigma_von: {sigma_von}")
print(f"Platform Case 1 (bottom face along hole axis) FOS: S_y / {sigma_von}")
sf = sy_p / sigma_von
print(f"Platform Case 1 FOS: {sf}")
print()

print("------------New Case------------")
print()
#platform case 2 calculations 1
print("Platform case 2 (cross section where pin holes c/d lies) calculations")
print("for (0, 0, +-d/2)")
k_p = 3.8
sigma_axial = k_p * sigma_d

print(f"Sigma_axial: {sigma_axial}")
```

```
#transverse
q = p_w/2*(((0.25+p_t)/4)**2-(0.25/2)**2)
transverse= 318.08*q/(I_y * p_w)

sigma_x = sigma_axial
r = math.sqrt((sigma_x/2)**2+transverse**2)
c = sigma_x / 2
sigma_1 = c + r
sigma_2 = c - r
sigma_von = math.sqrt(sigma1**2 + sigma2**2 -sigma1*sigma2)
print(f"Sigma_von: {sigma_von}")
print(f"Platform Case 2 FOS: S_y / {sigma_von}")
sf = sy_p / sigma_von
print(f"Platform Case 1 FOS: {sf}")

#platform case 2 calculations 2
print()
print("Platform case 2 calculations II")
print("for (+-d/2, 0, 0)")
k_p = 3.8
sigma_d = (174.37+143.71)/(p_t*p_w)
sigma_axial = k_p * sigma_d
print(f"Sigma_axial: {sigma_axial}")

#transverse
transverse= 4*318.08/(3*p_t*p_w)

sigma_x = sigma_axial
r = math.sqrt((sigma_x/2)**2+transverse**2)
c = sigma_x / 2
sigma_1 = c + r
sigma_2 = c - r
sigma_von = math.sqrt(sigma1**2 + sigma2**2 -sigma1*sigma2)
print(f"Sigma_von: {sigma_von}")
print(f"Platform Case 2 FOS (+- d/2, 0, 0): S_y / {sigma_von}")
print()
print("-------------New Case------------")
print()
print("Platform case 3 (at pinhole EF) calculations")
tmax = 4*318.08/(3*p_w*p_t)
print(f"tmax: {tmax}")
k = 3
```

```
torsion = 0.47*k
print(f"Torsion: {torsion}")
sigma_vm = math.sqrt(3*(torsion+tmax**2))

print(f"Platform Case 3 FOS: S_y / {sigma_vm}")
sf = sy_p / sigma_vm
print(f"Platform Case 1 FOS: {sf}")
print()
print("-------------New Case------------")
print()
#deflection
print("Platform Deflection Calculations")
y_max = F1*a1**2 * (a1 - 3*p_l) / (6*E*I_y) - F2*a2**2 * (a2 - 3*p_l)/(6*E*I_y)
print(f"deflection max: {y_max}")
fs = 0.01 / y_max
print(f"deflection FOS {fs}")
print()
print("-------------New Case------------")
print()
print("Arm Buckling Calculations")
print(f"{I_y}")
arm_I = (arm_t)**3*(arm_w)/12
P_cr = math.pi**2 * arm_E * arm_I / ((arm_l)**2)
print(f"P_cr: {P_cr}")
FOS = P_cr / F1
print(f"Buckling FOS: {FOS}")
#buckling
```