***Honor Statement:***

*An essential feature of the University of Tennessee, Knoxville, is a commitment to maintaining an atmosphere of intellectual integrity and academic honesty. As a student of the university, I pledge that I will neither knowingly give nor receive any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity.*

***Project Expectations:***

*I have personally written all the code, compiled all the graphs, computed all the handwork, and written all the text in this project. I have accurately cited when I used information obtained anywhere except lecture notes, office hours, and Norton's Design Textbook.*

Name: (Printed)

Will Buziak

Signature:

Date:

3/11/2022

## 1. Chosen Parameters:

| | Iteration 1 | Iteration 2 | Iteration 3 | Iteration 4 | Iteration 5 | Iteration 6 |
|---|---|---|---|---|---|---|
| Material | 1095 | 1010 | 1060 | 1045 | | |
| Condition | quench & temper @ 600 (F) | Hot rolled | Quench * temper @ 1000 F | Cold rolled | | |
| $S_y$ (kpsi) | 118 | 26 | 97 | 77 | | |
| $S_{ut}$ (kpsi) | 183 | 47 | 140 | 91 | | |
| D (in) | 3.75 | 3.75 | 3.2 | 10 | | |
| d (in) | .75 | .75 | 2.75 | 2.2 | | |

$Material =$ 1045 SAE Designation
Condition = Cold Rolled
$S_y =$ 77 kpsi
$S_{ut} =$ 91 kpsi
$D =$ 10 in.
$d =$ 2.2 in.

I chose Carbon Steel 1045 cold rolled. After looking at a substantially heavier material at a larger diameter and a much lighter material at a larger diameter. I was originally concerned with the weight of the bike arm and chose a light material, but decided that my bike was, hypothetically, not going to be used in high performance environments and therefore settled on a happy medium material at a slightly lower bar diameter of 3.2 in. With a hole diameter of .75 in. I am confident that the material will be able to withstand the loads for a long enough time and still fulfill the factor of safety requirement.

I fought a lot towards the end with the sizes of the diameters and settled on a larger diameter of 10 in. and a smaller diameter of 2.2. These were chosen because they produced a more desirable yield factor of safety.

## 2. Reaction Forces and Moments

After getting an idea what the FBD looks like and the forces that are active, just change in magnitude as the bike arm makes its way around. I decided to do the bulk calculation in matlab. I chose to go about this problem by iterating through theta with a for loop, and beginning it by passing the value of theta through an if statement that decides the value of F depending on which position the bike arm is in it then calculates the corresponding X, Y reaction forces and all three moments.

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| $R_{1_x}\ (lbs)$ | 0 | -529 | -635 | -449 | 0 | 449 | 635 | 449 |
| $R_{1_y}\ (lbs)$ | 497 | 351 | 0 | -272 | -384 | -272 | 0 | 272 |
| $R_{1z}\ (lbs)$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $M_{1x}\ (Torque)$ $(in-lb)$ | 480 | 339 | 0 | -19.8 | -28 | -19.8 | 0 | 19.8 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $M_{1y}\ (in - lb)$ | 0 | -339 | -28 | -19.8 | 0 | 19.8 | 28 | 19.8 |
| $M_{1z}\ (in - lb)$ | 1450 | 1030 | 0 | -813 | -1250 | -813 | 0 | 813 |

## 3. Individual Loading Diagrams

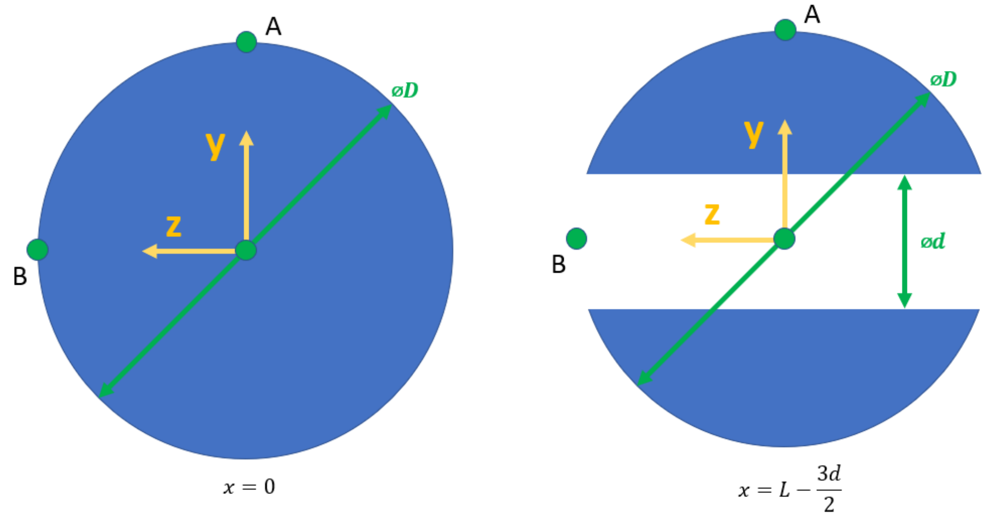


*Figure 1 Cross Section of Bike Arm*

a. *Maximum Stress caused by the Axial Load (in the x direction) (kpsi) :*

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| $A\ at\ x = 0$ | 0 | -6.74 | -8.09 | -5.72 | 0 | 5.72 | 8.09 | 5.72 |
| $B\ at\ x = 0$ | 0 | -6.74 | -8.09 | -5.72 | 0 | 5.72 | 8.09 | 5.72 |
| $A\ at\ x = L - 3d/2$ | 0 | -9.36 | -11.2 | -7.95 | 0 | 7.95 | 11.2 | 7.95 |

The stress in the axial load is consistent across the cross-section, therefore, A and B at x=0 are the same values per position.

b. *Maximum Stress caused by the Shear Load in the y direction (kpsi):*

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| $A\ at\ x = 0$ | 8.44 | 5.97 | 0 | -4.61 | -6.52 | -4.61 | 0 | 4.61 |
| $B\ at\ x = 0$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $A\ at\ x = L - 3d/2$ | 11.7 | 8.29 | 0 | -6.4 | -9.06 | -6.4 | 0 | 6.4 |

The stress only acts due to shear on the neutral axis, therefore, stress due to shear at B is zero

c. *Maximum Stress caused by the Moment about the x axis (Torque) (kpsi):*

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| $A\ at\ x = 0$ | 2.44 | 1.73 | 0 | -.101 | -.143 | -.101 | 0 | .101 |
| $B\ at\ x = 0$ | 2.44 | 1.73 | 0 | -.101 | -.143 | -.101 | 0 | .101 |
| $A\ at\ x = L - 3d/2$ | 6.59 | 4.66 | 0 | -.272 | -.385 | -.272 | 0 | .272 |

Torque acts in each location around the outer perimeter of the cross section, due to the y component of force and the distance a to the center of the pedal. However, if the bar is oriented vertically, or at theta = -90/90 degrees. Then the torque is zero.

d. *Maximum Stress caused by the Moment about the y axis (kspi):*

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| $A\ at\ x = 0$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $B\ at\ x = 0$ | 0 | -3.46 | -.285 | -.202 | 0 | .202 | .285 | .202 |
| $A\ at\ x = L - 3d/2$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The moment about the y is caused by the x component of the applied force, when the bar is oriented at an angle. Although this moment also only acts along the neutral axis, therefore it does not apply at both locations of A.

e. *Maximum Stress caused by the Moment about the z axis (kspi):*

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| $A\ at\ x = 0$ | 14.8 | 10.5 | 0 | -8.28 | -11.7 | -8.28 | 0 | 8.28 |
| $B\ at\ x = 0$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $A\ at\ x = L - 3d/2$ | 30 | 21.2 | 0 | -16.8 | -23.7 | -16.8 | 0 | 16.8 |

The moment only acts along the neutral axis of the applied force, y. Therefore, there is no stress caused by the moment at B.

f. *Von Mises stress at the points of interest (kpsi):*

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| $A\ at\ x = 0$ | 17.2 | 12.4 | 8.09 | 12.2 | 13.4 | 9.81 | 8.09 | 12.2 |
| $B\ at\ x = 0$ | 2.44 | 7.77 | 8.09 | 5.72 | .143 | 5.72 | 8.09 | 5.72 |
| $A\ at\ x = L - 3d/2$ | 32.9 | 23.5 | 11.2 | 20.9 | 25.4 | 18.3 | 11.2 | 20.9 |

Find the highest Von Mises stress for mean and alternating stress at the three important locations of on the beam. (All stresses should be in kspi.)

| | Peak | Base | Mean | Alternating |
|---|---|---|---|---|
| $A\ at\ x = 0$ | 17.2 | 8.09 | 12.7 | 4.57 |
| $B\ at\ x = 0$ | 8.09 | .143 | 4.12 | 3.98 |
| $A\ at\ x = L - 3d/2$ | 32.9 | 11.2 | 22.1 | 10.8 |

## 4. Strengths

Note: For this section only, in the excel sheet I carry more than 2 decimal places as I am unclear exactly which values require more precision.

| | |
|---|---|
| $S_y$ (kpsi) | 77 |
| $S_{ut}$ (kpsi) | 91 |
| $S_e'$(kpsi) | 45.5 |
| $C_{load}$ | .7 |
| $C_{size}$ | .6951 |
| $C_{surface}$ | .817 |
| $C_{reliability}$ | .868 |

| | |
|---|---|
| $S_e$(kpsi) | 15.7 |
| $S_m$ (kpsi) | 68.3 |
| $b$ | -.2127 |
| $A\ (kpsi * Cycle^{-b})$ | 1.5813 |
| $N$ (cycles) | 2016000 |
| $S_{f@N}$ (kpsi) | .0721 |

I decided to use a 95% reliability relating to a C reliability factor of .868. I chose this because the purpose for my bike arm is not in high performance and therefore, I can allow less of a reliability percentage, but since I do not expect it to be withstanding insane forces I do not expect it to perform 100% of the time.

## 5. Factors of Safety and Conclusions

There are two possible modes of failure. The first is that the part yields. The equation for FOS due to yielding is:

$$FOS_y = \frac{S_y}{\sigma_a + \sigma_m}$$

The Modified Goodman Fatigue FOS equation is:

$$FOS_f = \frac{S_f S_{ut}}{S_{ut}\sigma_a + S_f\sigma_m}$$

| | $FOS_y$ | $FOS_f$ |
|---|---|---|
| $A\ at\ x = 0$ | 4.5 | .01 |
| $B\ at\ x = 0$ | 9.5 | .01 |
| $A\ at\ x = L - 3d/2$ | 2.3 | .01 |

The fatigue factor of safety is likely incorrect, however still falls in the realm of possibility given the long time use of the bike arm.

Bike Arm FOS = 2.3

This does not meet the project requirement of a FOS between 5-9.9, however, not only is it 8 PM & I have been working on this code all week. I believe the issue comes from calculating and dealing with peak, base, mean and alternating stresses. I am not sure how because these calculations seemed up front, however towards the end of this project it was difficult to keep track of all the different variables. I am however, confident that it would be sufficient for most uses and is satisfactory for civilian use bike arms that are not for high performance purposes.

I was pleasantly surprised about how intensive the coding was for this project as I enjoy solving problems with matlab and enjoyed the experience with the For loop. However, I am not sure if I dealt with it properly or if my code was at fault for incorrect values. I encourage critiquing and feedback on my code.