SAE Mini Baja: Suspension and Steering

Design Selection and Analysis

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Overview

- Recap of Suspension and Steering Designs
- Suspension Analysis
- Steering Analysis
- Conclusion

Recap

- Front Suspension
  - Double A Arms

- Rear Suspension
  - Double A Arms

- Steering
  - Back Mounted

Suspension Analysis-Final Design

A-Shaped Members:

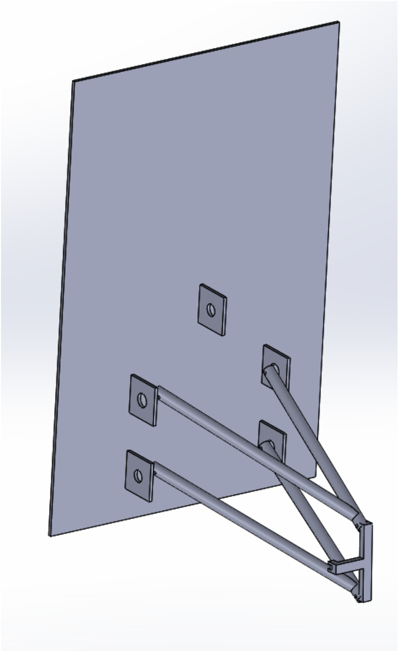
- Designed for weight reduction
- Simplistic

Pros:

- Strong against front impact
- Easy to manufacture
- Lightweight

Cons:

- Weaker in loading

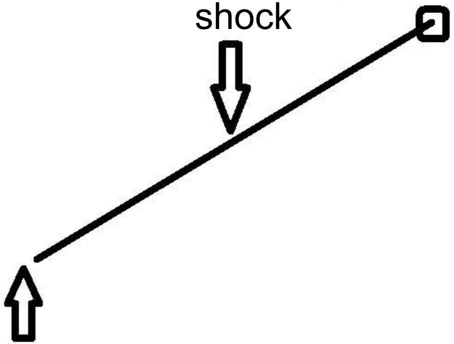


Nick Gary

Hand Calculations

Bending stress in A-arms

- Analysed half of one A-arm
- Hinge joint connecting to frame, force from vehicle weight, force of shock



Hand Calculations Cont.

Moment around hinge:

Force of shock= 325.83lbf

Sum of forces in Y direction:

Force of hinge Y dir=51.85lbf

Sum of forces in X direction:

Force of hinge X dir=124.66lbf

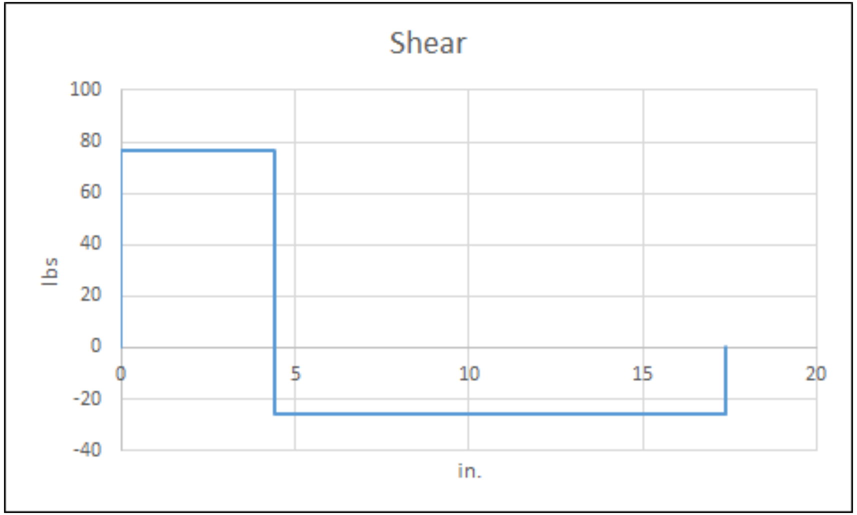
Half forces due to symmetric geometry:

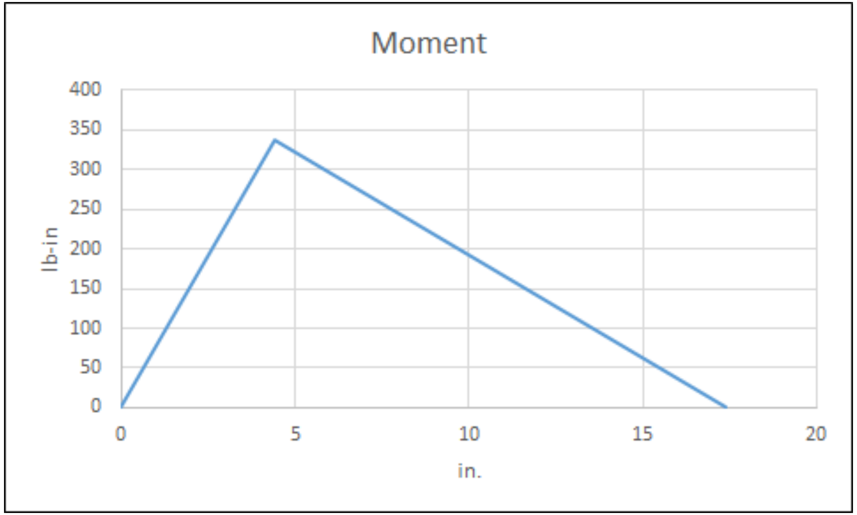
Force of shock= **162.92lbf**

Force of hinge Y dir= **25.93lbf**

Force of hinge X dir= **62.33lbf**

Hand Calculations Cont.





Max Moment = 337.04 lb-in

Hand Calculations Cont.

$$\sigma = \frac{Mc}{I}$$

$$I = \frac{\pi}{64}(D^4 - d^4)$$

$$c = \frac{D}{2}$$

M= 337.04lb-in

σ = 36ksi for Structural A36

d=0.8D

Output:

D=**.78in**, d=**.624in**

FOS of 2:

D=**.98in**, d=**.78in**

Shock Placement

- After performing dynamic analysis on the suspension design, the forces experienced by the members can be greatly mitigated by mounting the shock as close as possible to the wheel hub.
- There are physical limitations on how close to the hub the shocks can get, such as: extended length of the shocks, desired ride height, and potential interference.

Nick Gary

Stress Analysis

- Axial loading of the members is going to be ignored, because stresses caused by bending will far exceed them.
- The member the shock mounts to will experience the largest force in the system, so it will fail first.
- The bolts for the members will also be a mode of failure when the suspension receives a front or side impact. The shear stress on the bolts will be calculated using the axial loading on the members.

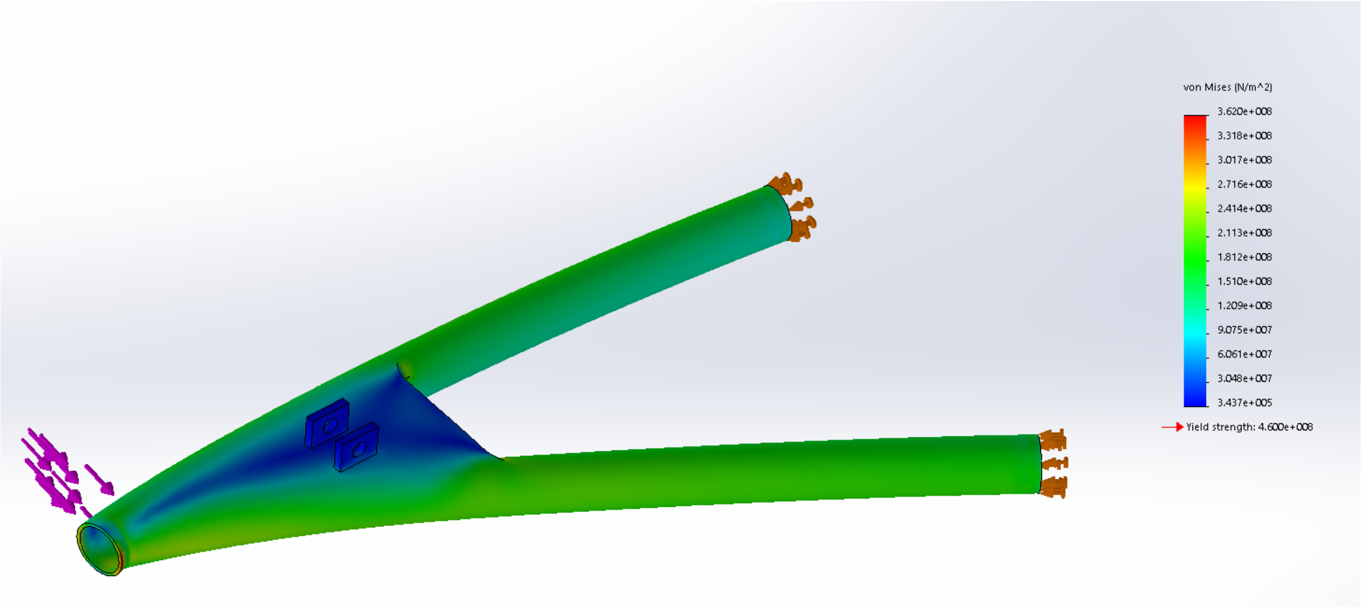
Nick Gary

Stress Analysis- Front Impact

<u>Situation:</u>

- 25 mph impact on one tire
- Simulates the car suddenly hitting an object, like a tree or rock, and coming to a full stop
- The chosen material is 4130 steel with a OD of 1.25in and an ID of 1.15in
- The load was applied to the end of one A arm, with the a arm fixed to where it would mount to the chassis

(cont.)



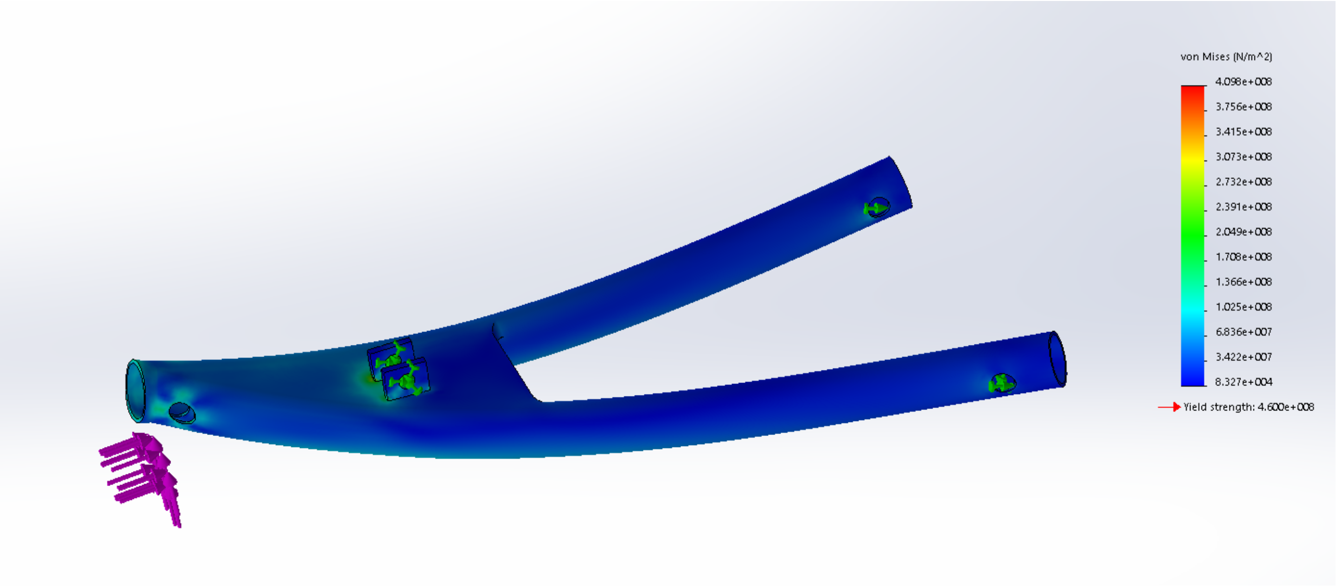
- The lowest factor of safety for this loading 2.1
- The force applied in this loading is an extreme case

Stress Analysis-Vertical Loading

Situation:

- The car jumps off a surface from 3 ft and lands crooked on only one wheel
- Same material and dimensions as the previous design scenario
- The load is applied vertically to the end of the A arm as well as axially
- The A arm is pinned at the shock mount and the chassis mount

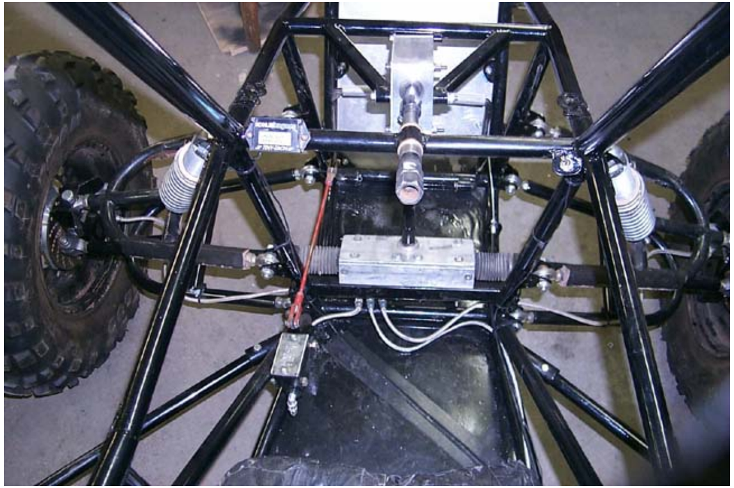
(cont.)



- The minimum factor of safety for this situation is 3.2
- This loading is an extreme case due to the suspension bottoming out before it reaches stress levels this high

Steering Design Selection

- **<u>Back Mounted Steering</u>**
  - Minor modification to existing hub
  - Front of frame constraints
  - Room for tie rod mounting to hub (Brake Caliper)



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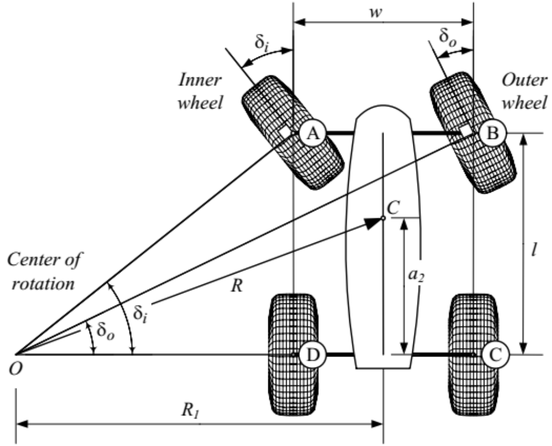
Steering Analysis - Akerman Angles

- Ackerman Steering Angles
  - Inside wheel turns at greater angle than outside wheel
  - Determine max angle of both tires such that a U-turn can be achieved within a width of 2 lanes (144 in)



Inside Tire Maximum Angle

$$\tan(\delta_i) = \frac{L}{R_1 - \frac{W}{2}}$$

Outside Tire Maximum Angle

$$\tan(\delta_o) = \frac{L}{R_1 - \frac{W}{2}}$$

Zane Cross

Ackerman Angles Calculations

- Track Width = **W** = 49 in
- Wheelbase = **L** = 65 in
- Mid-Radius = **R(1)** = 155.5 in

After inputting variables into formula and solving……

<u>Max Turning Angles</u>

- Inside Tire = **35.54 Degrees**
- Outside Tire = **24.90 Degrees**

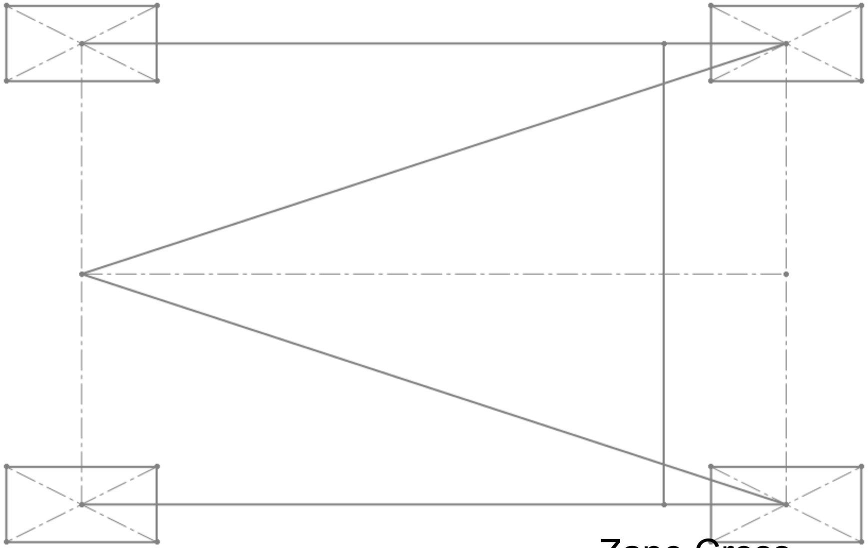
<u>Turning Radius</u>

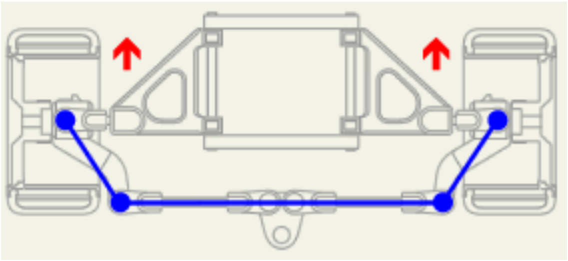
- **9.63 ft**

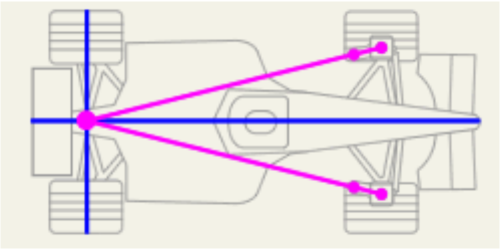
Zane Cross

Steering Analysis - Tie Rod Mount

- Determine where the tie rods are mounted to the hub of the vehicle to achieve an Akerman Angle with zero toe on turn in







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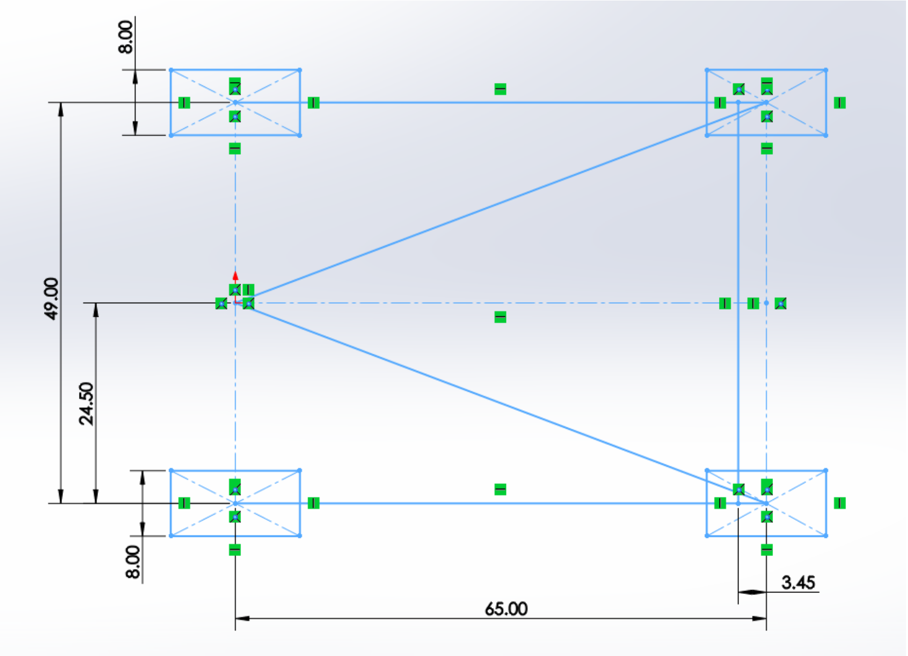
Tie Rod Mount Calculations

- Through the use of similar triangles…..

$$\frac{24.5}{65} = \frac{y}{3.45}$$

$$y = 1.43\ in$$



Steering Analysis - Steering Ratios

- Determine the ratio of the rack to pinion to give the right amount of assist in the steering system
- 1:2 Steering Quickener currently installed
- Remove steering quickener to regain 12:1 steering ratio of original steering rack

Steering Analysis - Tie Rod Force

- Determine axial force tie rod encounters when hitting an obstacle and coming to a complete stop

$$F_{Rock} = M_V * A$$

Situation

- Velocity of Vehicle is 20 mph
- After hitting obstacle, vehicle comes to a complete stop in 0.5 sec

$$M_{Kingpin} = F_{Rock} * d_1$$

Solution

- $F_{Tie\ Rod}$ = **1,269.86 lbf**

$$F_{Tie\ Rod} = \frac{M_{Kingpin}}{d_2}$$

Steering Analysis - Tie Rod Buckling

$$F_{Tie\ Rod} = \frac{\pi^2 EI}{(KL)^2}$$

$$I_x = \frac{\pi}{64} D^4$$

- $F_{Tie\ Rod}$ = 1,269.86 lbf
- E = $(29.0 * 10^6)$ psi (A36 Steel)
- K = 1.0 (Pinned Support at both ends)
- L = 15 in

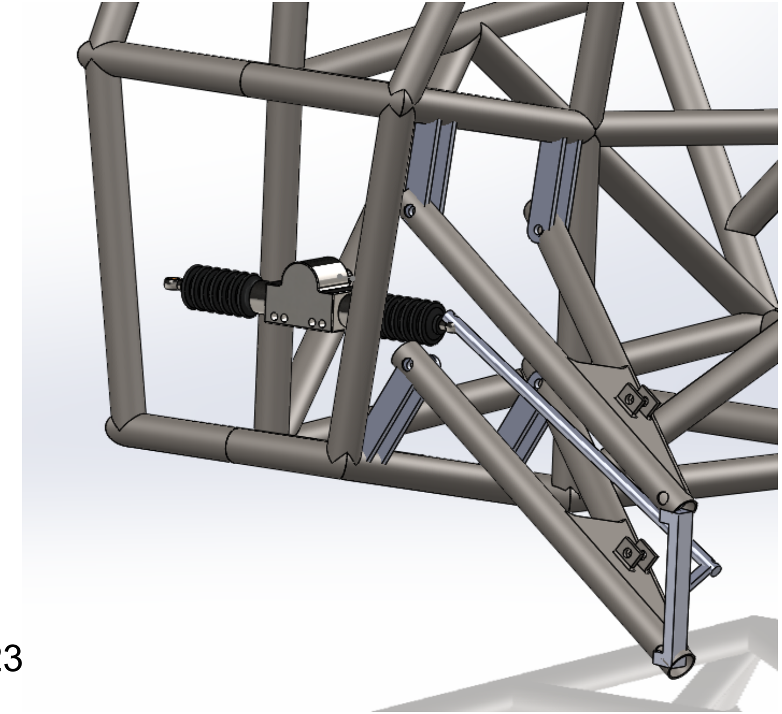
After solving for I, then solving for diameter…..

Tie Rod Dimension

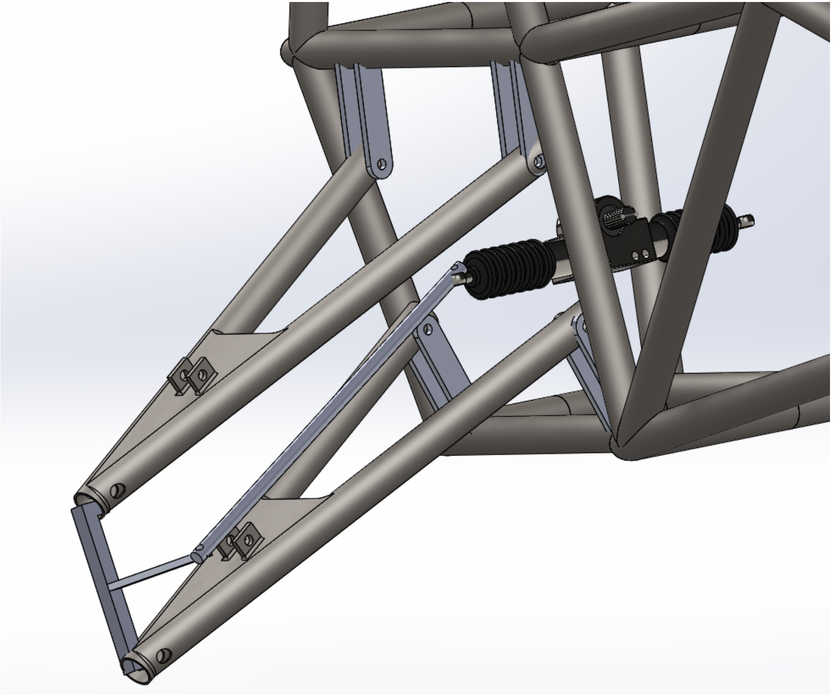
- Safety Factor of 2
- **D = .4491 in**

Final Assembly

Front Isometric View



Back Isometric View



Conclusion

- Front Suspension
  - Double A-Arm
  - Material chosen is 4130 steel with a OD of 1.25in and an ID of 1.15in

- Steering
  - Back Mounted Steering
  - D = .4491 in

References

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