RC Cor

Original copy given to Jack Q.
OG page

3/2/2022

Chassis Brainstorm

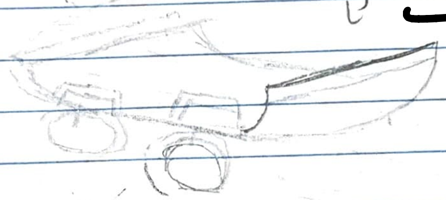
→ Unibody or body on frame

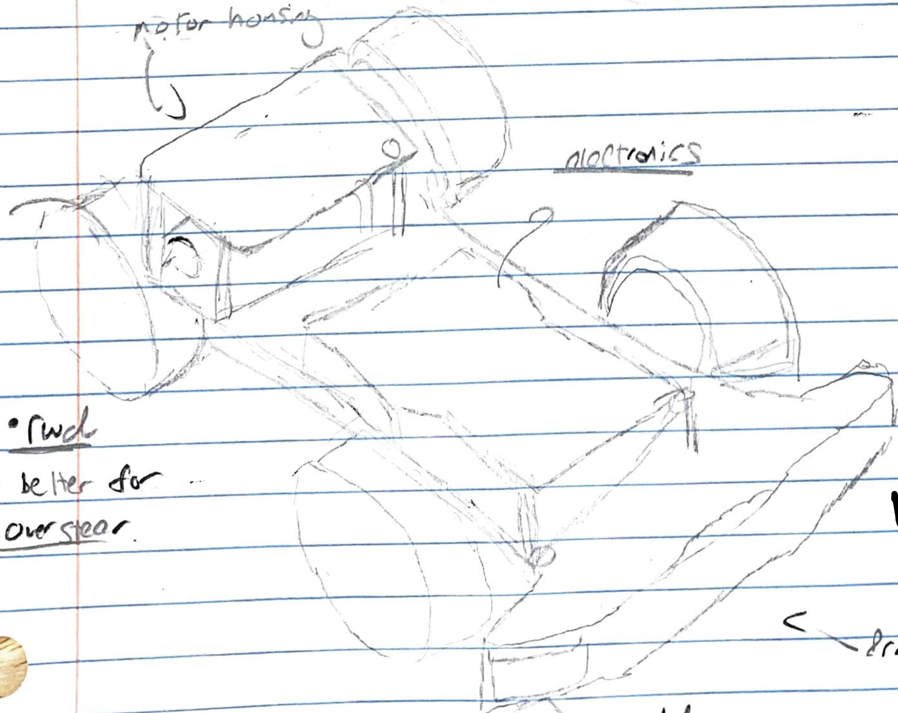
→ Chassis material: wood?

- Acrylic → laser cut
- Abs + fiberglass → additive manufacturing
- Addition: Onyx, PLA 12 reinforced glass fiber.

$50 budget

Curved chassis? → difficult to produce





• rwd
• better for oversteer

protective bumper/bullbar

add protective foam to reduce impact force.

Milestone 1 : Chassis and Axle design

Slides from Dr. Tehrani's lectures

Top speed and acceleration calculations.

Track perimeter : 40m

Target a completion in 5 seconds as a higher expectation

assuming no velocity magnitude change (even at turns)

V_{max} (average) $\approx \frac{40}{5} = \underline{8 m/s}$ → but real racing line is shorter, so about 7m/s.

This safely falls below the max velocity in a 1:1 ratio with the motor rotating at $\underline{18{,}000 \text{ rpm}}$.

$V \in [7, 8]$ → a range of 7, 8 m/s likely realistically

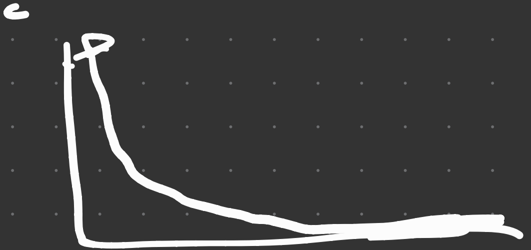
Variance accounts for slip, surface conditions and racing line changes,

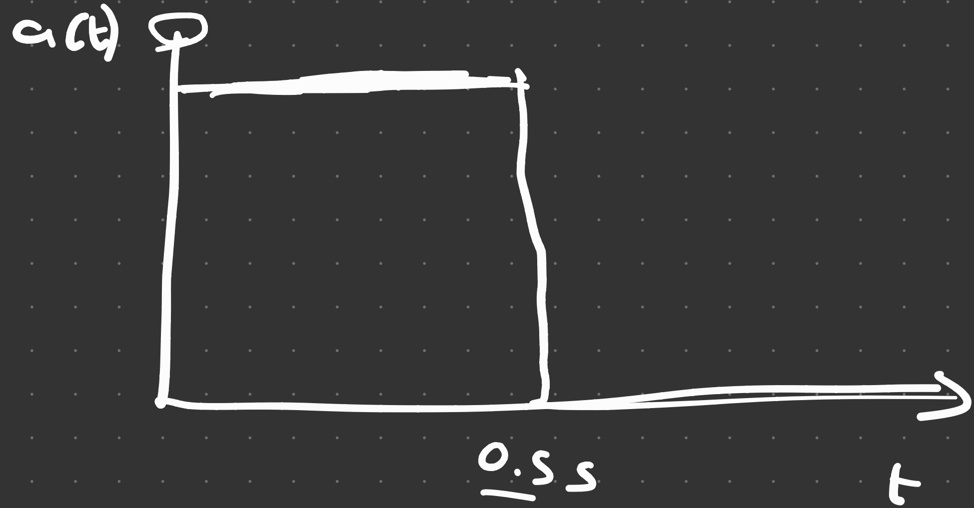
acceleration → maximizing acceleration and designing for that

$a_{target} = a_{max}$

assumption:
frictionless

acceleration is on a **transient**





assume this is the a(t) **profile**.

$V = v_i + at$ $\quad V_i = 0 \quad$ so $\quad v_{max} = at$

$8 = a(0.5)$ → $\underline{a = 16\,m/s^2}$

before it zeros out.

Confirm values by checking with motor input late

$P = T \cdot \omega_{motor_{max}}$ P from power of battery

Torque rating

use $V_{max} = r \cdot \omega_{out}$

$\omega_{out} = \frac{V_{max}}{r}$

use transmission gearing ratio to obtain ω_{in} theoretical

Check if $\omega_{in_{theoretical}} > \omega_{motor_{max}}$ Cube load)

Similarly $a = \alpha_{out_{theoretical}} \cdot r$ $\alpha_{out\text{-}theoretical} \rightarrow \alpha_{in\ theoretical}$

$T_m = I_{shaft} \cdot \alpha_{in\ motor}$

Check if $\alpha_{in\ theoretical} > \alpha_{in\ motor}$

$U_{max} \approx 8\,m/s$

$a_{max} \approx 16\,m/s$

Find reaction forces at max speed and max acceleration

Do not know effective Power, but one can compute Drag force

$$F_d = 0.5 \times \rho \times C_d \times A \times V^2$$

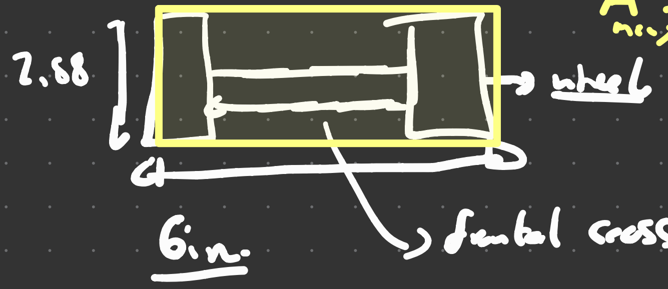
use max frontal area

$C_d = 0.8$

@ 20°C, 1atm

$F_d = 0.3894\,N$

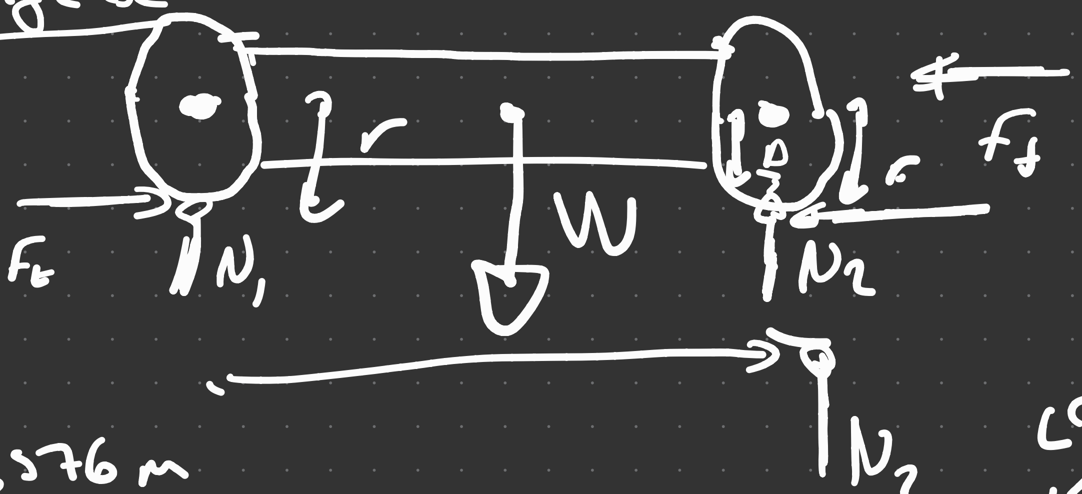
$2.88 \times 6\,in =$



$A_{max} = 2.88 \times 6.8\,in$

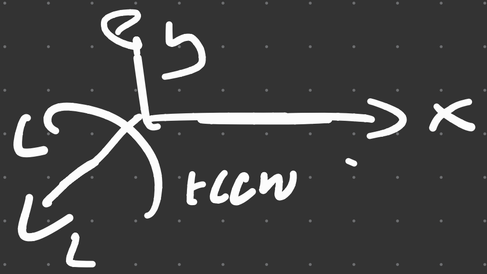
A_{max} yields F_d max which yields max reaction forces

Const velocity case



Note: ignore rolling resistance until more info.

acceleration decreases until



$r = 0.036576\ m$

→ 10 in wheelbase

$= 0.254\ m$

wheelbase $= W_b$

In the max acceleration case from launch,

• The design is set up such that the chassis' center height is one radius above ground.

later accounting for rolling resistance

$F_{r1} = C_{rr} N_1$

$F_{r2} = C_{rr} N_2$

C_{rr} → rubber/concrete

0.015

at constant velocity, all opposing friction effects cancel

ft $\sum F_y = 0 \rightarrow N_1 + N_2 = W$

$\sum F_x = 0$

$\rightarrow F_t = F_d \quad \underline{= 0.48\ N}$

$$\sum M_{rear} = 0 = \left(\frac{-w_b}{2}\right)(W) + N_2(w_b) + F_d(r) = 0$$

$$N_2(w_b) = \frac{w_b}{2}(W) - F_d(r)$$

$$N_2 = \frac{1}{2}(W) - F_d\left(\frac{r}{w_b}\right)$$

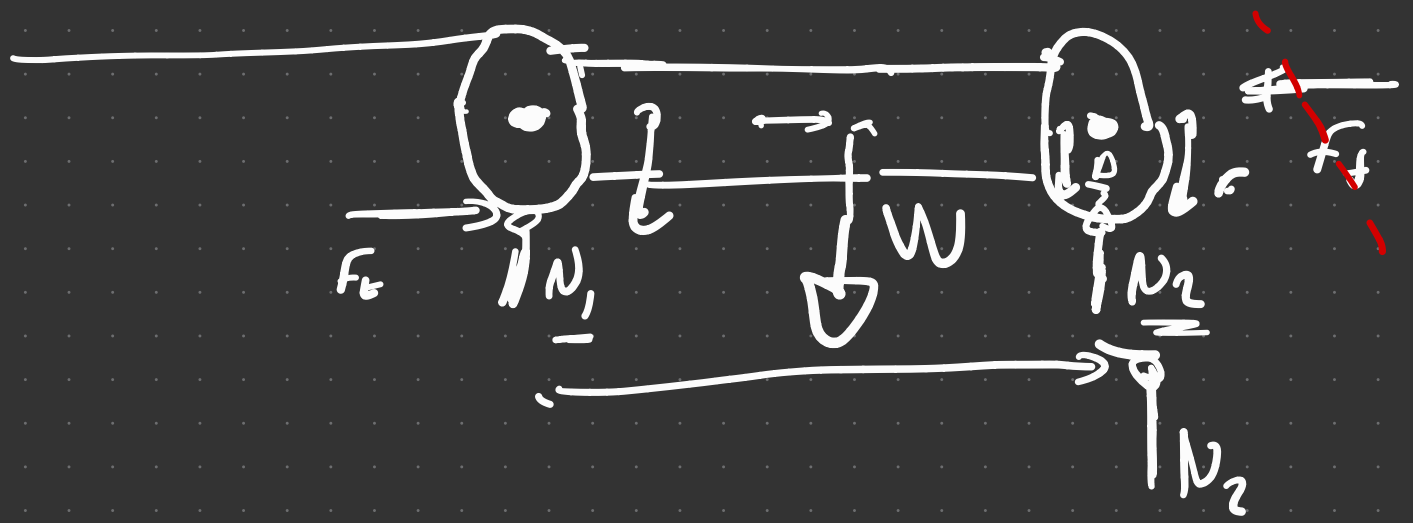
$$N_2 = \frac{1}{2}W - F_d\left(\frac{r}{w_b}\right)$$

$$N_1 = W - N_2$$

$N_2 = 4.835\ N$

$N_1 = 4.975\ N$

max acceleration case, @ $v = 0$ $F_f = 0$ → (no drag)



$F_{reb} = 8\ N = F_t$

Similar analysis

$\Sigma F_x = F_t = 0$

$\Sigma F_y = 0 \rightarrow N_1 + N_2 = W$

analyze around center of mass

$N_1 = W - N_2$

$$N_2(wb) - N_1(wb) + F_t(r) = 0$$

$$N_2 \cdot wb - (W - N_2)wb + F_t(r) = 0$$

$$N_2 wb - W \cdot wb + N_2 wb + F_t(r) = 0$$

$$2N_2 wb = W \cdot wb - F_t(r)$$

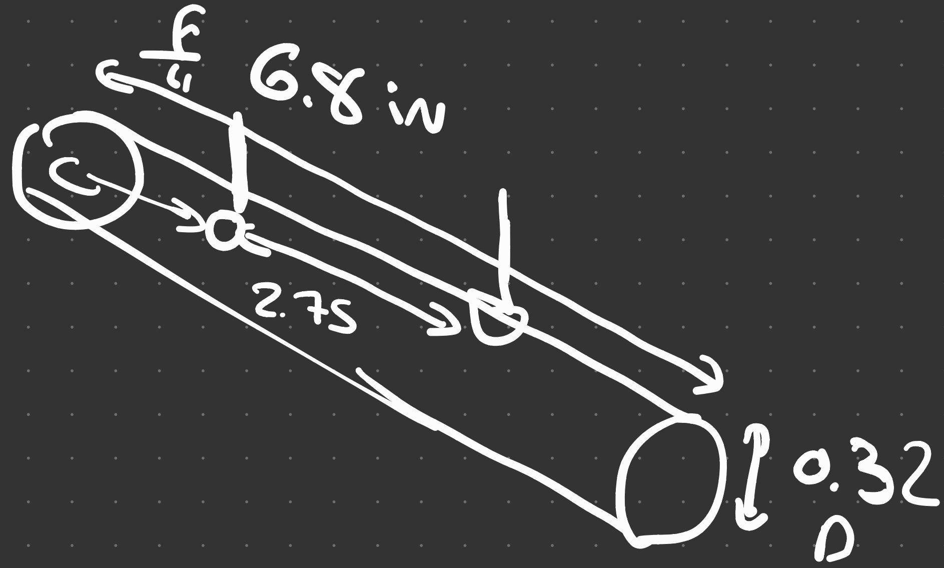
$$N_2 = \frac{W}{2} - \frac{F_t}{2}\left(\frac{r}{wb}\right)$$

$N_1 = W - N_2$

$$N_1 = \frac{W}{2} + \frac{F_t}{2}\left(\frac{r}{wb}\right)$$

$N_2 = 4.329\,N$

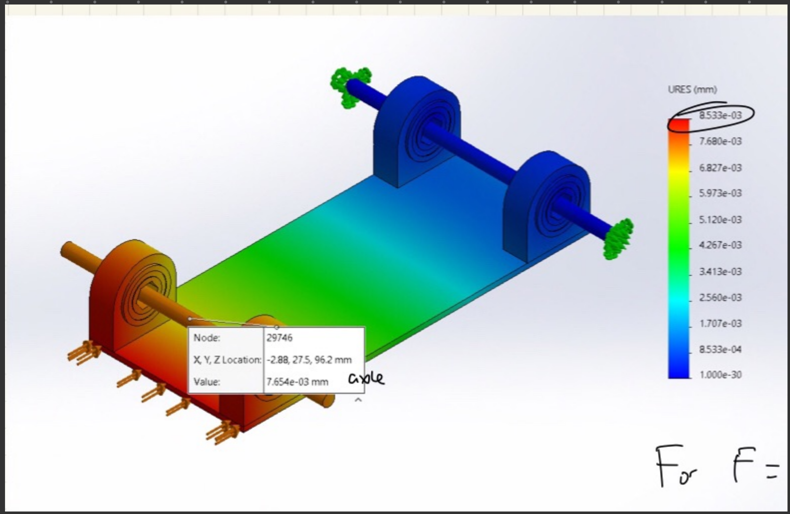
$N_1 = 5.481\,N$

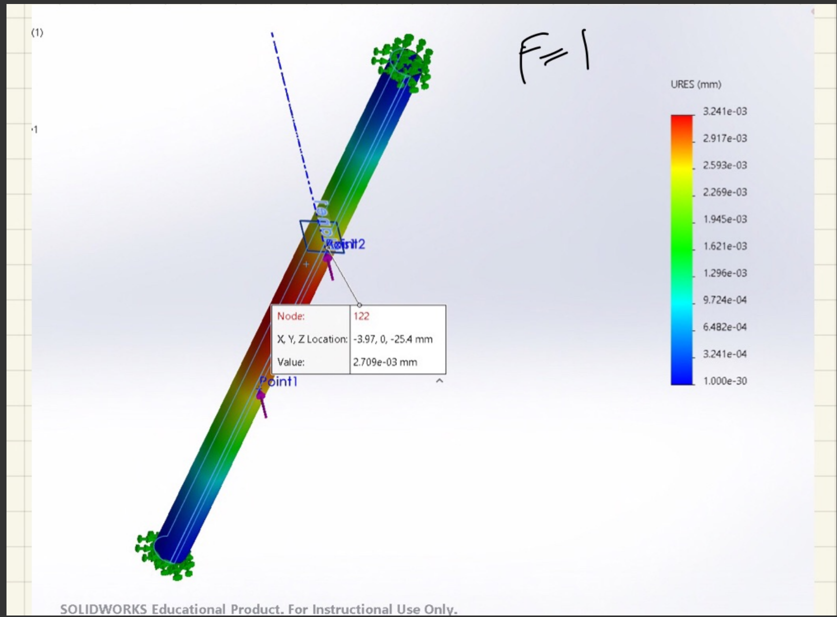


$$A_{cross} = 0.13 \times 4 = 0.52\ in^2$$

$$= \underline{0.000335\ m^2}$$

Use Dr. Tehrani's notes for FEA





$\delta_{axle} = 2.709 \cdot 10^{-6}$ m

$\delta_{chassis} = 8.535 \times 10^{-6}$ m

$\Rightarrow K = \frac{1}{\delta}$

$K_{axle} = 369140$ N/m

$K_{chassis} = 117192$ N/m

$$K_{total} = \left(\frac{1}{K_{chassis}} + 2\left(\frac{1}{K_{axle}}\right)\right)^{-1}$$

$$= 71679.51 \text{ N/m}$$

$n = 1, m = 1\text{kg}$

$$F_i = V_{max}\sqrt{mK \cdot n}$$

$$= 8\sqrt{71679.5} = 2141.8 \text{ N} = \underline{F_{impact}}$$

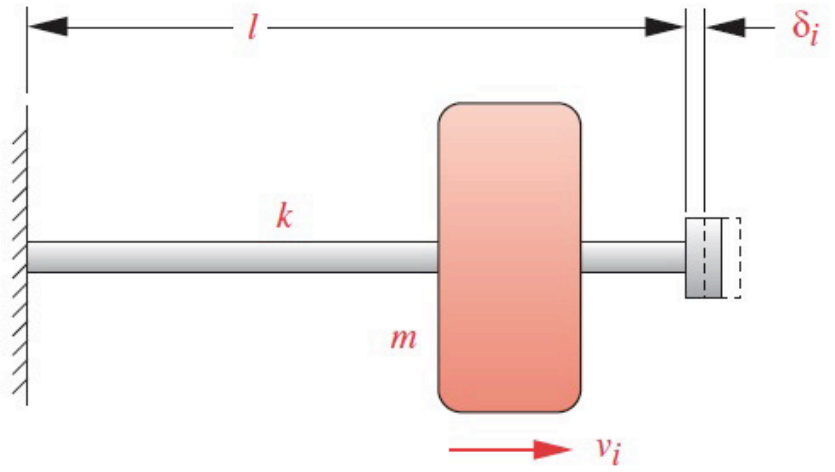
Check with Dr. Tehrani's notes

Calculating Impact Forces

3 times - (20s)

- V_i = Velocity of your car
- m = mass of your car
- η = 1 for elastic collision
- K = stiffness of car body
  - Calculate in FEA by:
    1. Ground drive wheels
    2. Apply force to impact point
    3. Use FEA to calculate deflection of car body between point where load was applied and where the wheels are grounded
    4. Use force and deflection to calculate stiffness

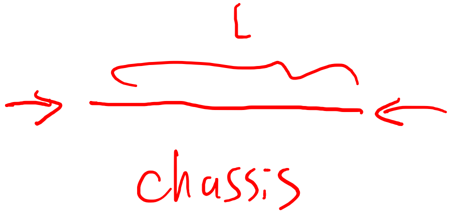
$$F_i = v_i\sqrt{\eta m k}$$



(Stresses) → chassis
→ axles

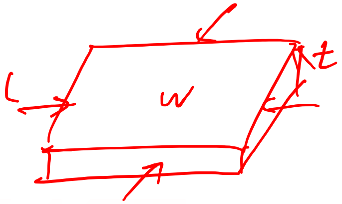
$\delta = \frac{PL^3}{3EI} \rightarrow P = \frac{3EI}{L^3}\,\delta$ ← example.

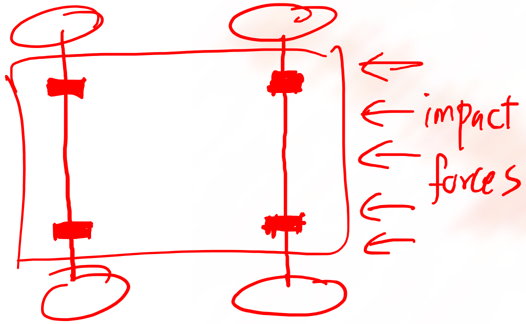
k

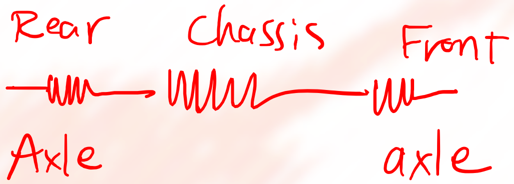


$\sigma = E\varepsilon \rightarrow \frac{F}{A} = E\frac{\delta}{L} \rightarrow F = \frac{EA}{L}\,\delta$

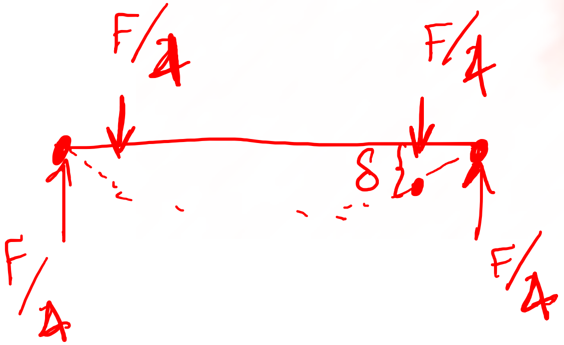
K







$\frac{1}{K} = \frac{1}{K_{R\,axle}} + \frac{1}{K_{F\,axle}} + \frac{1}{K_{chassis}}$



K_{axles}

$F = K_{axle}\,\delta$

(Maximus Stresses)

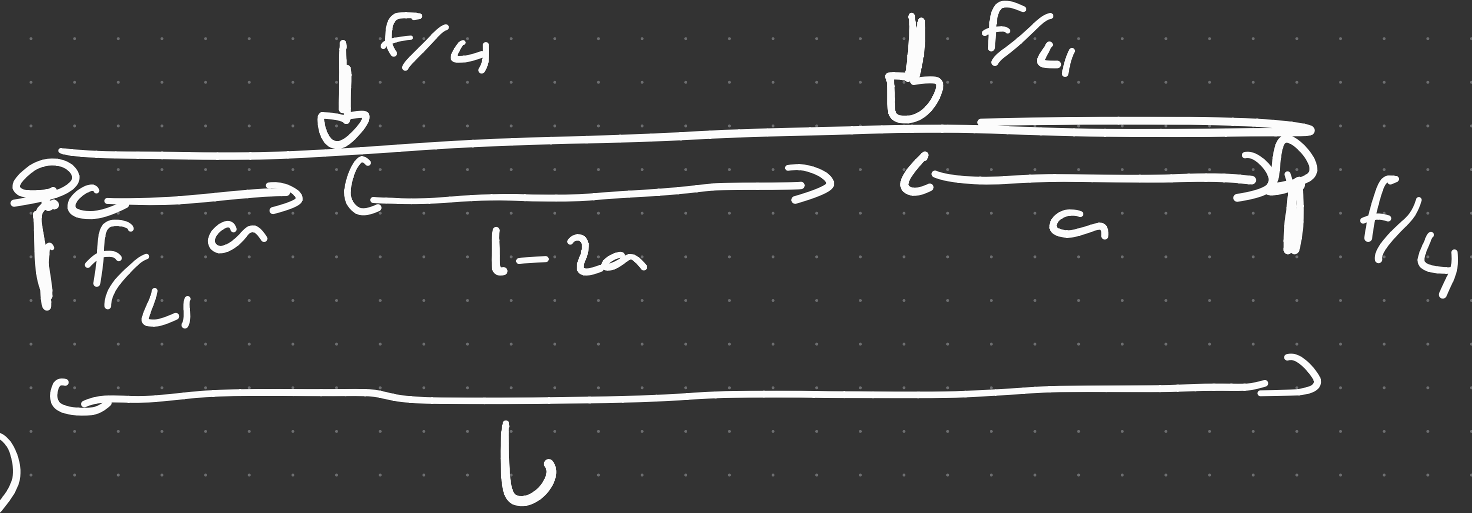
(Ductile - Failure)

(Brittle Failure)

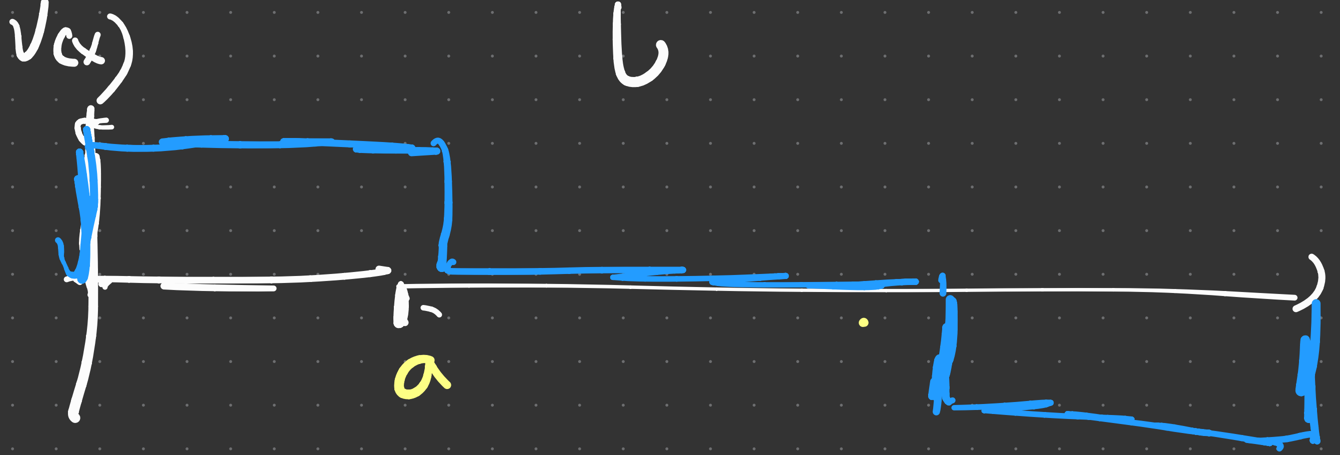
$$\sigma_{chassis} = -\frac{F}{A} = \frac{2141.84}{0.000335} = \underline{6393552.239}\ Pa \text{ from FEA}$$

$$\sigma_{chassis} = -6.394\ MPa$$

↳ compressive



$a = 51.435$ mm



with ideal rotation, no torsion. Later we can account for fatigue.

Statically, only bending exists.

$$\sigma_{max} = \left| \frac{My}{I} \right| = \left| \frac{\frac{F}{4}a \cdot y_{max}}{\frac{\pi D^4}{64}} \right|$$

$$\sigma_{max} = \frac{F}{4} a \cdot \frac{64}{\pi D^4} \left(\frac{D}{2} \right)$$

$$\sigma_{max_{axle}} = \frac{-8Fa}{\pi D^3}$$

$a = 0.051435$

$D = 0.008128\ m$

$$\sigma_{max_{axle}} = \frac{8(2141.84)\cdot(0.051435)}{\pi(0.008128)^3} = 574.65\ MPa$$

Safety factor from research

1.8 chassis, 2.2 axle

axle → 6061 Aluminum → Ductile

Onyx strain at break → 58% > 5% → brittle

$S_y = 241\ MPa$ for 6061-T6 aluminum

↳ axle

S_y chassis

↳

Use M.SS for 6061-T6 alumin

$$n = \frac{\frac{S_y}{2}}{\tau_{max}} = \frac{\frac{S_y}{2}}{\frac{\sigma_1 - \sigma_3}{2}} = \frac{S_y}{\sigma_1 - \sigma_3}$$

only one-directional sigma exists

$$\sigma_A, \sigma_B = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_A, \sigma_B = \frac{\sigma_x}{2} \pm \frac{\sigma_x}{2}$$

$\sigma_1 = \sigma_x \qquad \sigma_1 - \sigma_3 = 574.65$

$\sigma_2 = 0$

$\sigma_3 = 0 \qquad n = \dfrac{241}{574.65} = 0.41994$

$\sigma_1 - \sigma_3 = \sigma_1$

↳ axles fail. Consider thicker.

Also, Dr. Tehrani said this was fine

(high impact, $n = 1$)

added remark

Onyx Brittle

Use Modified Mohr

$$\sigma_A \geq 0 \geq \sigma_B$$

$$\left|\frac{\sigma_B}{\sigma_A}\right| \leq T$$

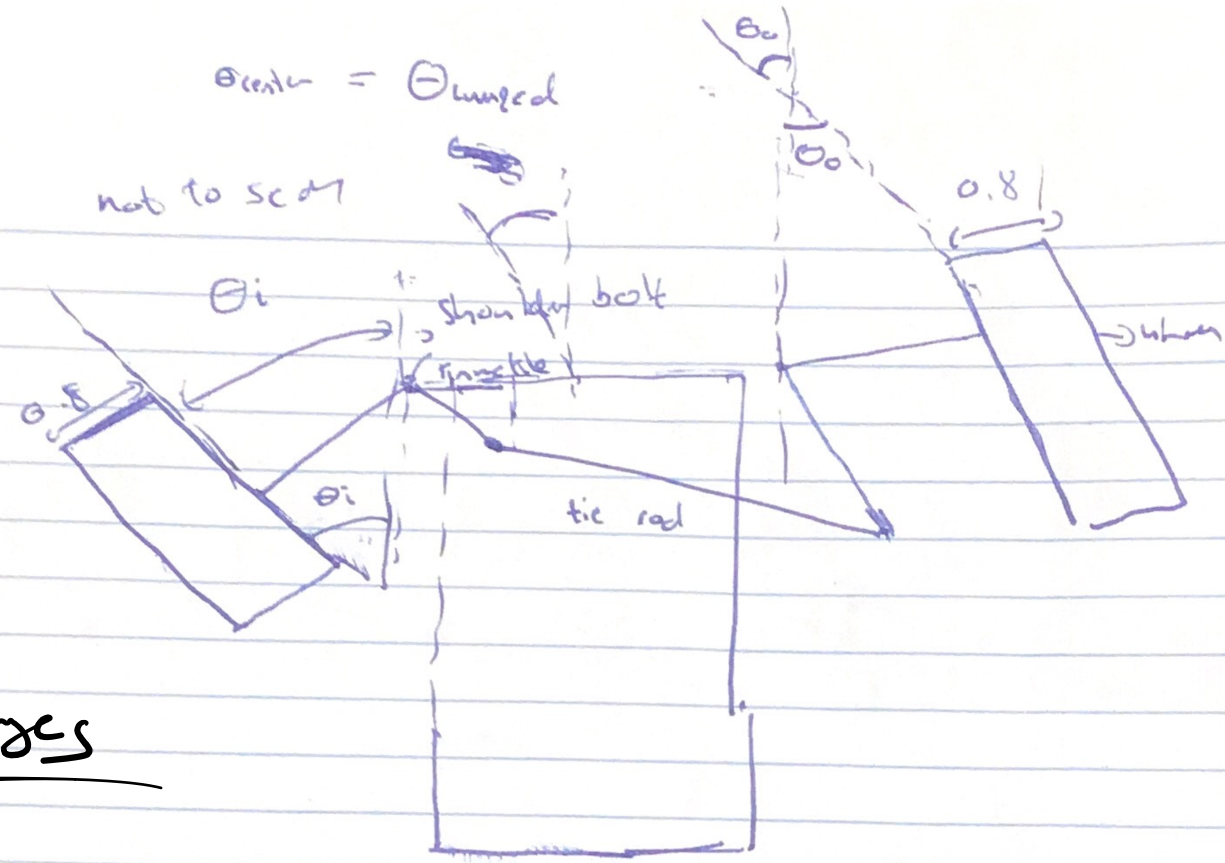
$$\sigma_A = \frac{S_{ut}}{n}$$

Onyx chart 800 MPa = S_{ut}
(Carbon)

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

$$n = \frac{800}{6.394} = 125.117$$ Safety factor

Check Later



See images

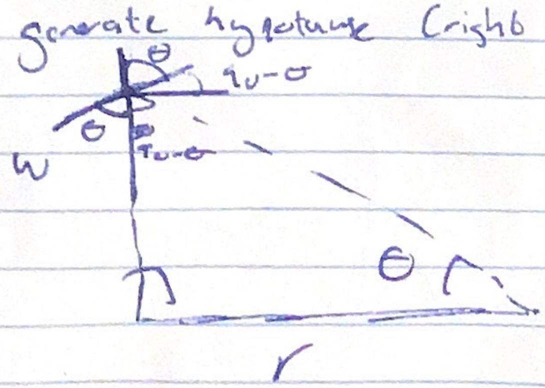
when does max angle occur? when the higher of θ_i and θ_o have the edge of the wheel hit the base plate?

- By animating on Solidworks

(note that ~~$\theta_o > \theta_{in}$) always~~ $\theta_{in} > \theta_{out}$

$$\boxed{\begin{aligned}\theta_{in} &= 34.93^\circ \\ \theta_{out} &= 29.44^\circ\end{aligned}}$$

generate hypotenuse (right angle triangle)



$$\tan(\theta) = \frac{w}{r}$$

w → wheelbase

r → radius

$\boxed{w = 10 \text{ in}}$

$$r = \frac{w}{\tan(\theta)}$$

$$\boxed{r = w\cot(\theta)}$$

- Calculate for inner and outer.

$$\boxed{\begin{aligned} r_i &= w\cot(\theta_i) \\ r_i &= 10\cot(34.93^\circ) \\ r_i &= 14.319 \text{ in} \end{aligned}}$$

$$\boxed{\begin{aligned} r_o &= w\cot(\theta_o) \\ r_o &= 10\cot(29.44) \\ r_o &= 17.716 \\ r_o &= \boxed{17.72} \text{ in} \end{aligned}}$$

$$r_{central} = r_{ave} = \frac{r_i + r_o}{2}$$

$$\boxed{r_{ave}} = \frac{14.319 + 17.72}{2} = \boxed{16.0195 \text{ in}} \rightarrow \boxed{\text{Steering radius}}$$

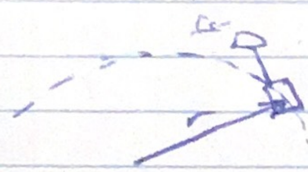
centered steering angle

$$\arctan\left(\frac{w}{r}\right) = \theta_c$$

$$\theta_c = \arctan\left(\frac{10}{16.0195}\right)$$

$$\boxed{\theta_c = 31.974^\circ}$$

Skidding



Friction btw tires and track

$$\mu N = \frac{m v^2}{r}$$

$$\boxed{v = \sqrt{\frac{\mu N r}{m}}}$$

r = steering radius

what to use

$r = 16.0195 \text{ in} = 0.4068953 \text{ m}$

assume 0 tangential ~~[illegible]~~ acceleration;

- constant velocity
- use sum of normal forces

$$N = N_{front\ tire} + N_{back\ tire} = \boxed{N_1 + N_2}$$

$$\boxed{N = 4.975 + 4.835 = 9.81 \text{ N}} = mg = 1\text{kg} \cdot 9.81 \text{s}^{-2}$$

$\mu \approx 1.0$

~~[illegible]~~ from several sources, dry concrete, and rubber

~~$\mu = 0.6$~~ → worst case from Engineering Toolbox. with higher ~~[illegible]~~ static friction, higher speeds possible.

. However, it is important to avoid slip, which can result in a crash

~~$V = \sqrt{\frac{0.6(9.81)(0.4068953)}{(1\,kg)}}$~~

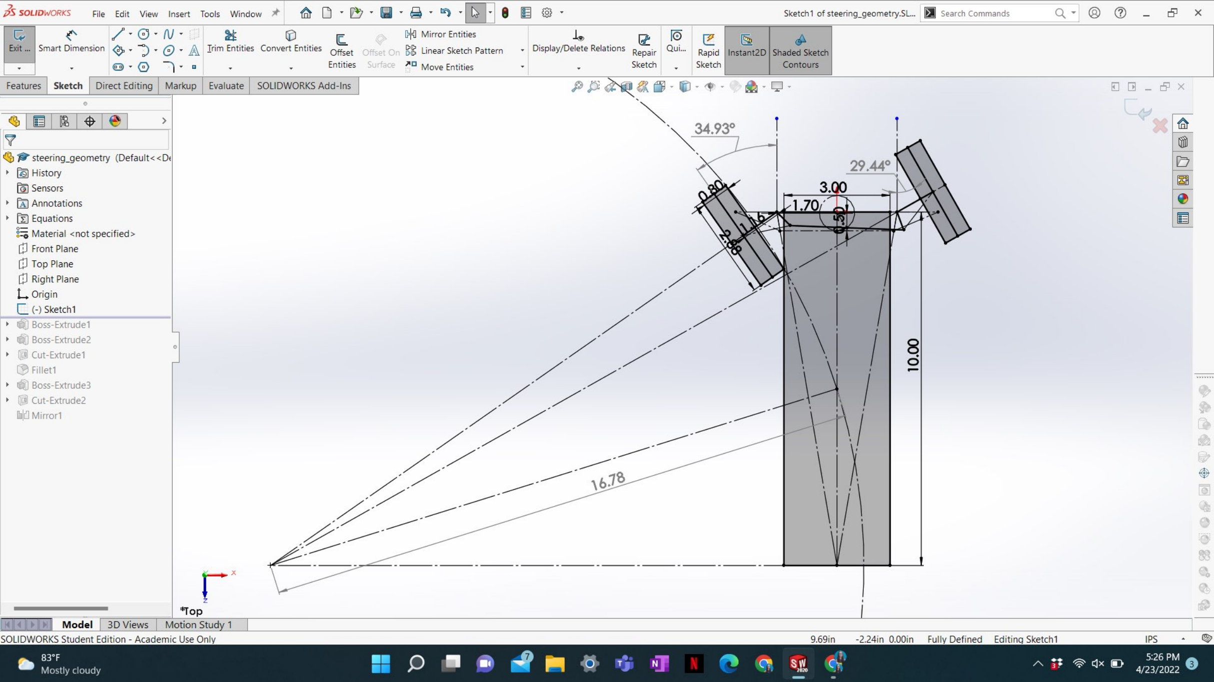
~~$V = 1.54574$~~

~~$V \approx 1.55m$ in the conservative case~~

$$V = \sqrt{\frac{(1.0)(9.81)(0.4068953)}{(1\,kg)}}$$

$$\boxed{V = 1.9979\,ms^{-1}}$$

$V \approx 2ms^{-1}$ around ~~[illegible]~~ turn at max.


SOLIDWORKS
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Sketch1 of steering_geometry.SL...
Search Commands
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Smart Dimension
Trim Entities
Convert Entities
Offset Entities
Offset On Surface
Mirror Entities
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Shaded Sketch Contours
Features
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Boss-Extrude2
Cut-Extrude1
Fillet1
Boss-Extrude3
Cut-Extrude2
Mirror1
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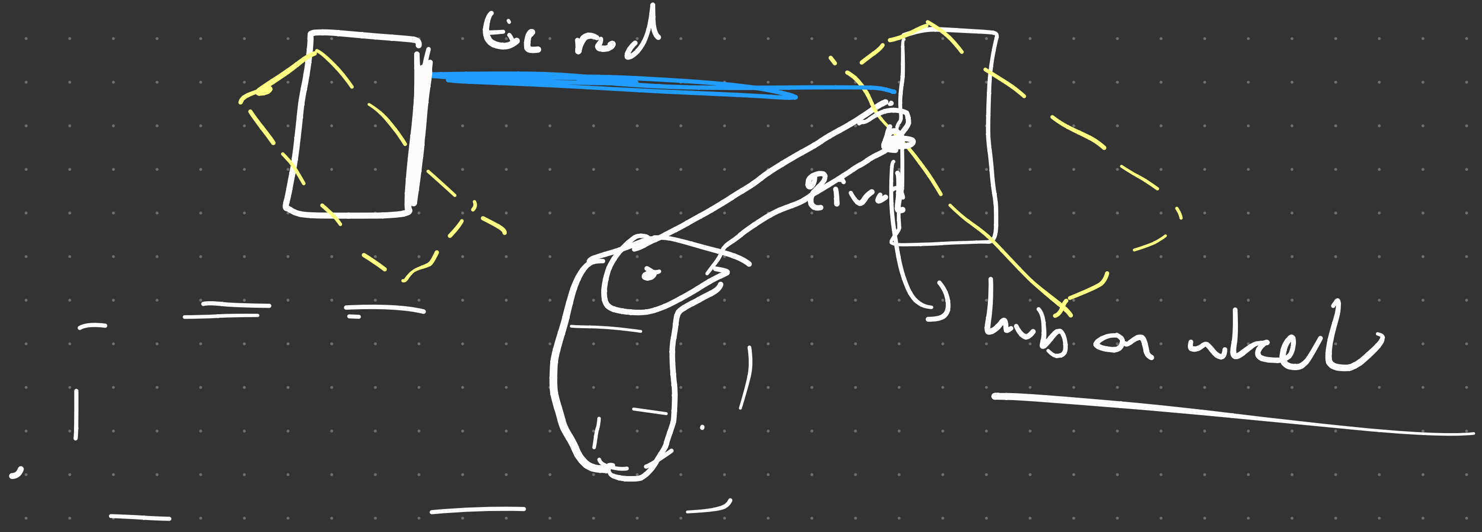
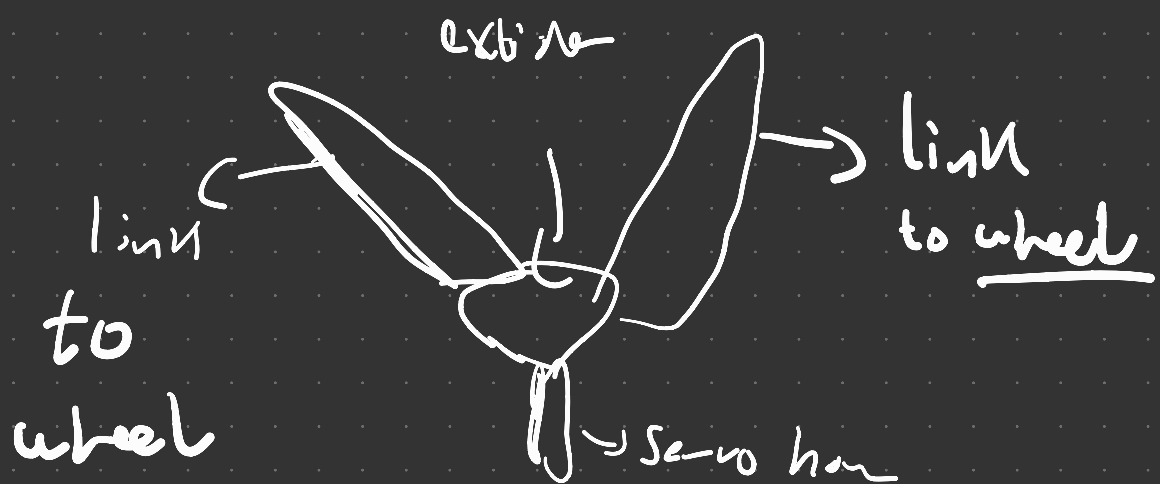


Switch to symetric steering for simplicity ?



Stage 1, Stage 2, Diff

Joints and drivetrain

1:23 ratio? way too low!

$1.53\,ms^{-1}$ top speed

1:9 more suitable

$$F = \frac{T}{r} = \frac{1.764}{0.0365} = 48.33N$$

$C_{rr} = 0.01$

$T_{stall} = 0.196\ Nm$

$D = 73mm$

Incorrect calculations by teammate. Jack says he will account for normal force difference at back wheels

Joints?

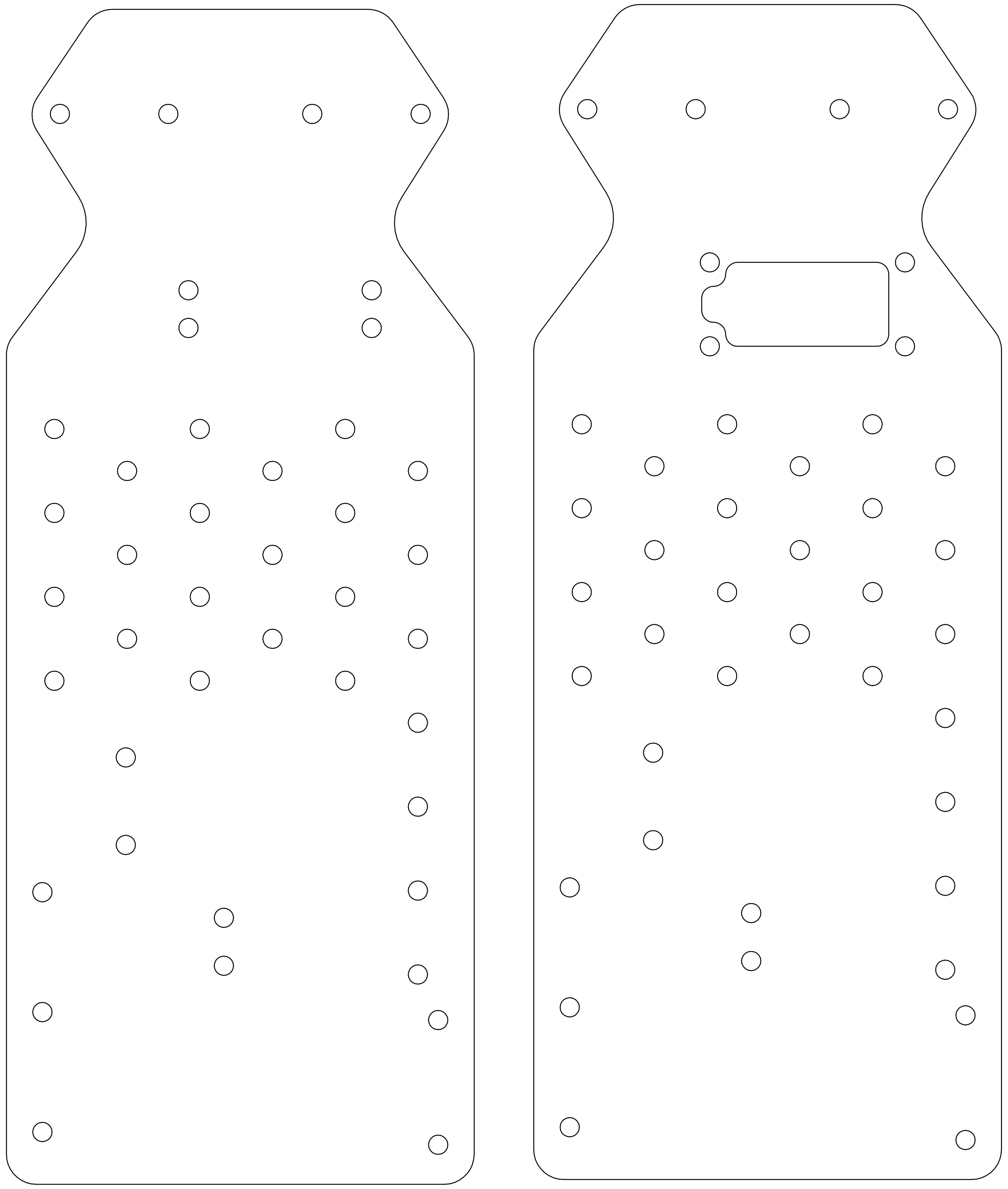
→ Modular → 3D printed parts → heat set inserts
(top and bottom)

2 plates as bellypans sandwich parts
and secure with bolt.

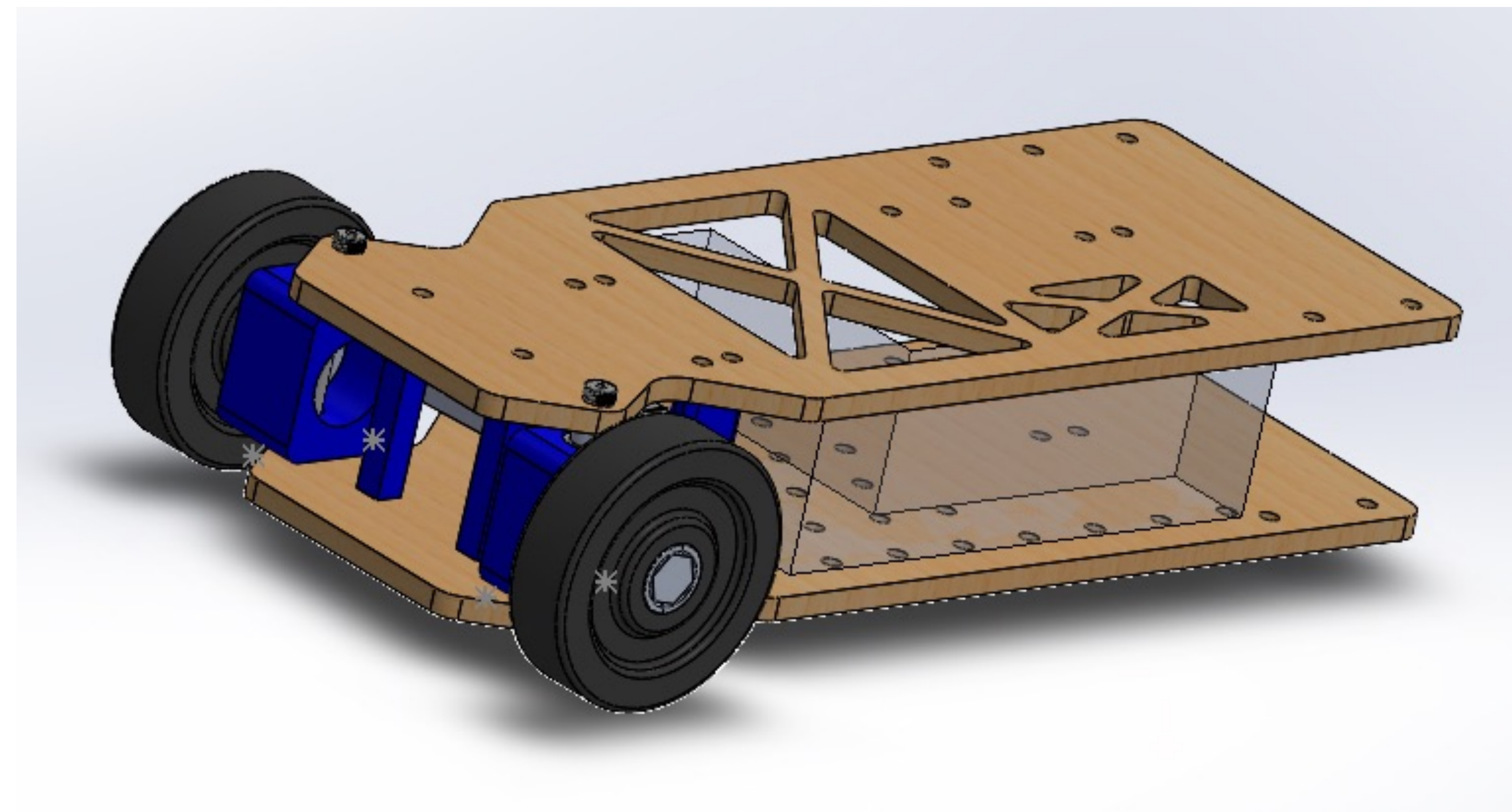
Milled/CNC'd aluminum? ins

Onyx body cannot fit printer as one unibody.

Reinforcement Suggested by 2rot



Idea for bellypan



Suggested layout

Maddie will finalize CAD assembly and redo it.

Manufacturing:

Daniel will laser-cut bellypan from wood (birch plywood), saves time and money.

My role: Use onyx for reinforced steering knuckle!

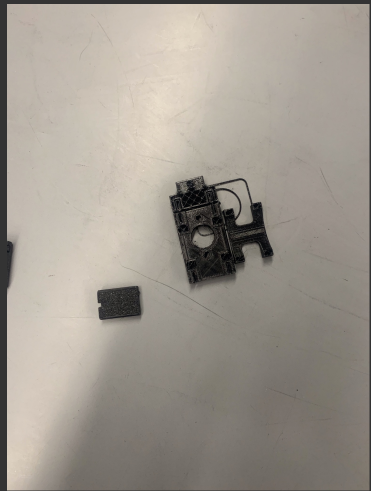
TIW overcrowded, use onyx to avoid wait.

Print mounts from PETG / PLA

update: PETG used for availability

2 iterations needed.

First one had tolerance too loose for bearing.



failed print with PETG

USB fell out.

request overnight print.

Successful print

not our part from 'Completed print' bin. Returned to TIW to owner