STEERING RACK HOUSING FEA W/ WET DATA 12/31/23

Loads

- driver turning steering wheel full-steer and wheel bumps smth
- driver pushing into steering wheel
- full-steer no wheel turn
- maybe slanted from tie rod?

Overview of tie rods

- bump-steer: amt the wheel turns when you bump into smth (want to minimize)
  - → when driver tries to hold wheel straight when bumping into smth
    - → puts tie rods in compression and yikes
      - → force goes into the rods rather than steering rack
        - → since this yr we fixed the tie rod issue, now the loads will go into the steering rack so steering rack likely to fail
- tie rod is 1st pt of constraint
  - → w/o it, the wheel would be floppy
  - → another node for force to transfer through
    - → lots of force goes through it bc of that

FEA Setup

- full-steer
  → bump bushing against clevis
  → wheel bumps smith
- apply load
- constrain part
- screw forces
  → bolt pretension
- bearing fixture
  → allows rotation
- 6061-T6 (not 6061 Alloy) → remember to check material
- rule of thumb: 3 nodes on a face
- run Study
  → stress
  → disp
  → strain
  → FOS
- Should def run assembly FEA
  → run supports housing, too!

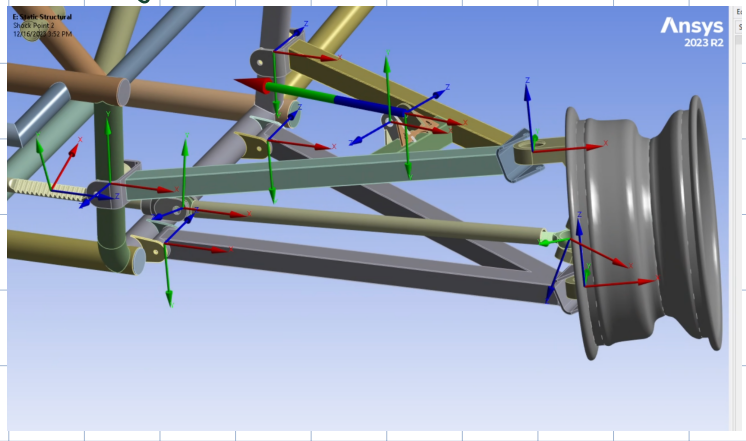
Material

- usually run to deflection (not to failure)

FEA

- static
- transient - ~~static~~ structural
  - → FEA over time (moving-ish)
  - → good for large assemblies (large displacement)
- rigid-body
  - → solve a free-body diagram?
  - → what are the resultant forces?
  - → I.e. applied force to wheel rod from the analysis give the forces seen at each joint
    - ↑ resultant
    - ↳ basically the resulting force "translated" due to constraints
      - → this is what meshes are

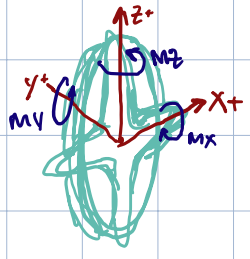
- FOS = $\frac{\text{max stress}}{\text{work/design stress}}$
  - → at any node, there is a certain amount of stress
  - → FOS < 1 means work/design stress is bigger than max stress so yield
    - → either pin assembly wrong or design sucks



- each coordinate system is a set of load cases at a joint
  - → each node is a coord system

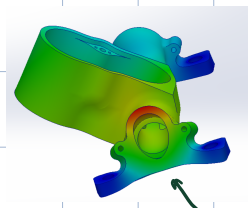
How WFT collected Data

- relative to hub face
  - → therefore Z-axis rotation isn't exact?
    - → Mz is steering (wheel turning) but isn't actual rotation of the hub, it's offset
    - → Mz is important bc it's the amt of load transferred to the rod
    - → there's a transfer of loads from wheel to steering axis
      - → the forces must the same

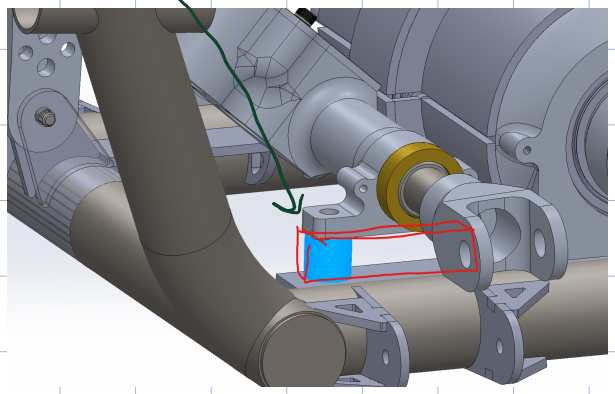


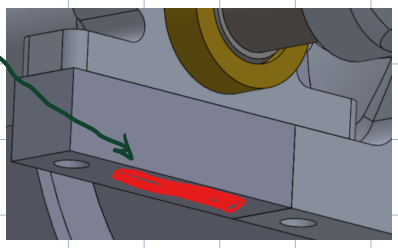
Action Items from 12/31/23

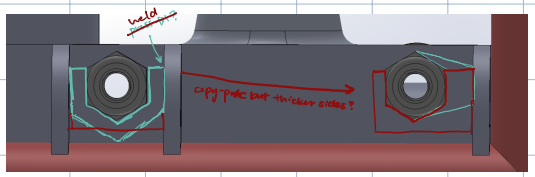
- ✓ open Front Inboard Assembly
  - ✓ CAD blocks that support entire clamp of housing
    - ✓ cutout in middle for weight reduction?
      - → does that affect support for clamp?
- ✓ find bolts on McMaster
  - → button head (bigger head ø 0.437") or socket head (smaller head ø 0.375")?
    - → non-loc hole ø is 0.307" so maybe 0.375" is a bit close
  - → should be 1.75" long according to internet, or at least two threads past nut
- ✓ washers on non-locating bolt holes
  - → literally only one washer on McMaster works bc of limited OD
- ✓ find nuts that fit
- ✓ CAD small piece that keeps nuts from rotating
- ✓? rerun in assembly w/ rack (tmr 1/1/24)

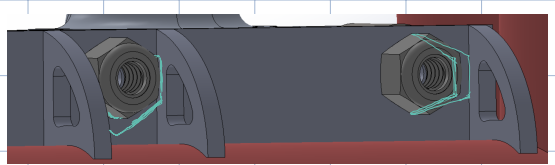


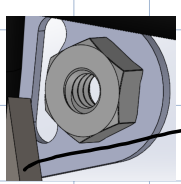
risk of clamp support...





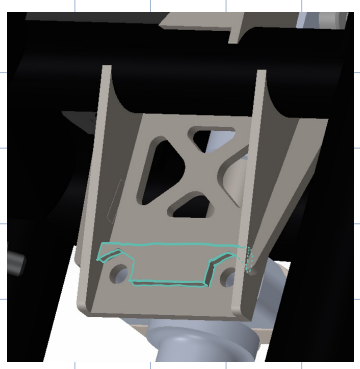






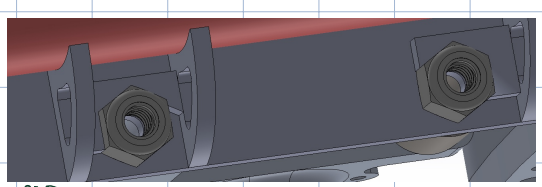
- round tabs cut then literally welded → must make → tab which makes things → lot easier
  - → it's a McMaster part (93560A140)

1/3/24



- round again!

yaymie 01/01/2024 19:46
so we had a tab with cutouts for the nut and it was welded onto the other tab
so like double layer thickness tab
if you look at the steering rack tabs from last year, you might see it



CAD

Questions

- Why are the corners filleted on the housing clamps?
  - → prob stress conc
- How do you determine washer size systematically? or do you literally just guess?
- How do you determine screw size systematically?
- Does meshing w/ mesh controls stink?
  - → ex) making out fine in normal mesh and fine again for a certain face
- Pillow block material? C63000?
  - → through harden or carburize harden

FEA Setup w/ Assembly

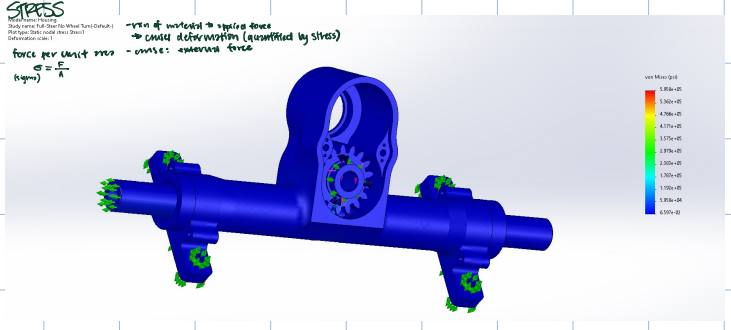
1/1/24

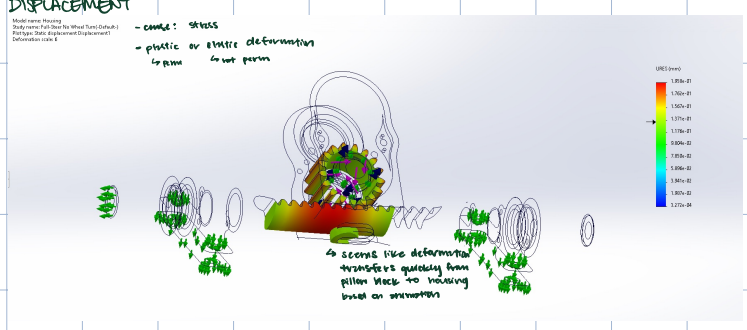
- Ammar's (Full-Steer No Turn)
  - → force thru tie rod so upward angled force on rack
- walkthrough
  - → don't cut: axis, bearing, cover (exclude these in part)
  - → cut: rack and housing → bc don't need to complicate to full extent
  - → load interactions
    - → type
      - → blue bar: where force is coming from
      - → pink: the rest
  - → set to really coarse first time to see if runs which tells you if fixtures are good
    - → then make finer on and on until adequate mesh to define stress concentration

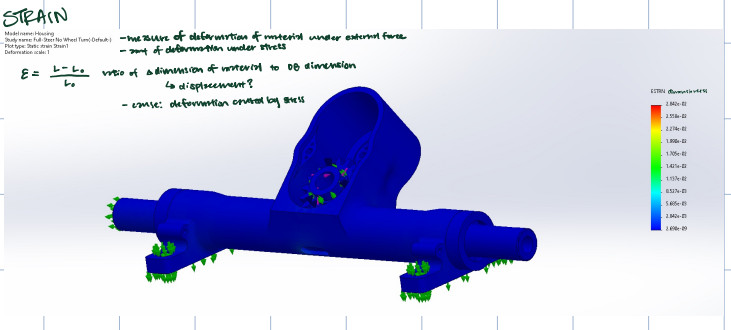
FEA

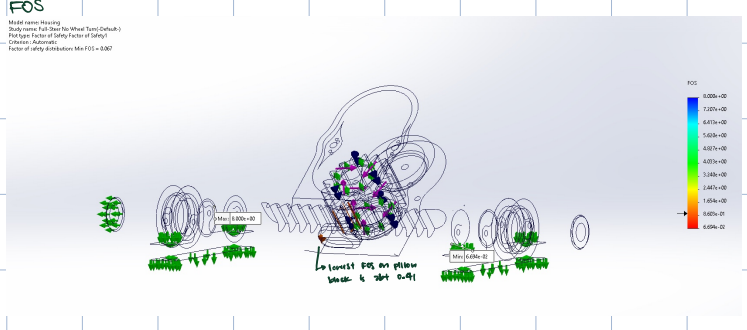
- Daniel's recitation
  - → pillow block + the shoulder is "perfectly square" so SW doesn't know what to do w it?
- basically the stress conc will prob be less severe the finer the mesh is?
  - → concluded from limited experience, can't really confirm bc Liam said "that's the turn of it"
    - → maybe Ammar knows?

added slight fillet but doesn't do anything









Heat Treating (Daniel's overview)

- different for core and shell?

- types

  → through?

    → core and surface hardened so very brittle (inelastic), breaks easily when deformed
    ↳ like compressed

    → good for tension cases

  → carburized

    → only surface hardened so doesn't break as easily when deformed (elastic)

    → good for compression cases

Optimizing Pillow Block and Pillow Block Shoulder FOS

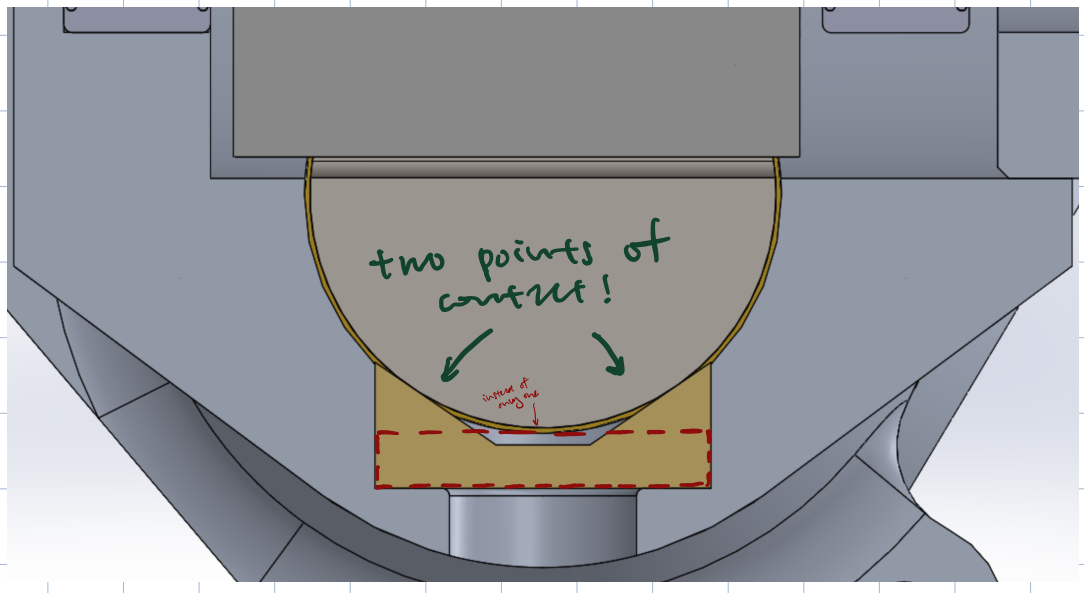
1/15/24

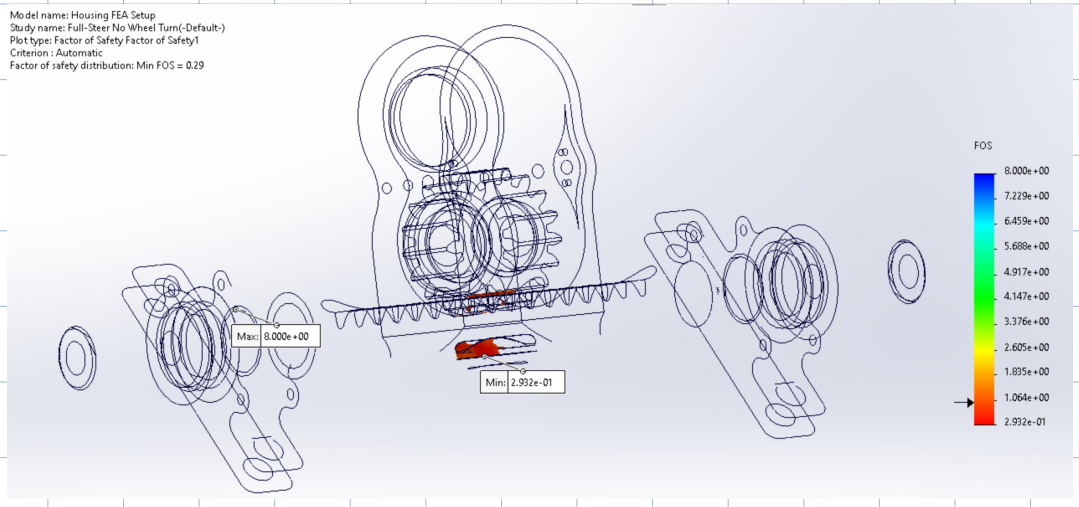
- previous min FOS on shoulder: 0.41
- change material to C36000 (not C63000)

	SRH	PB	SRH	PB	SRH	PB	SRH	PB
	0.15	0.0365	0.125	0.0615	0.1125	0.074	0.10025	0.08025
min FOS	0.82	0.09569	0.86	0.1312	0.92	0.1391	0.95	0.1486

Daniel's Enlightenment

1/22/24





MIN FOS 0.2932!!!

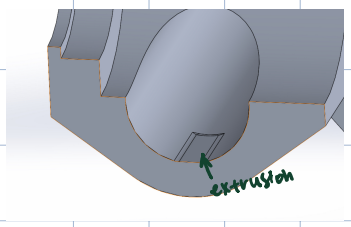
(previously 0.1486)

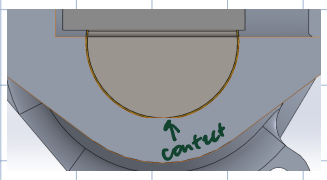
1/24/24

- forgot to save dimensions so min FOS is not as high as 0.2932 anymore
- need to figure out geometry behind maximizing FOS

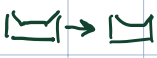
New Procedure...

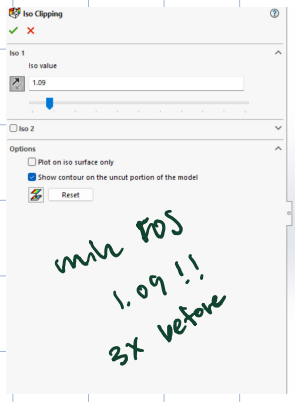
- suppress hole
  - → no more pillow block
  - → add extrusion in SRH to contact steering rlk

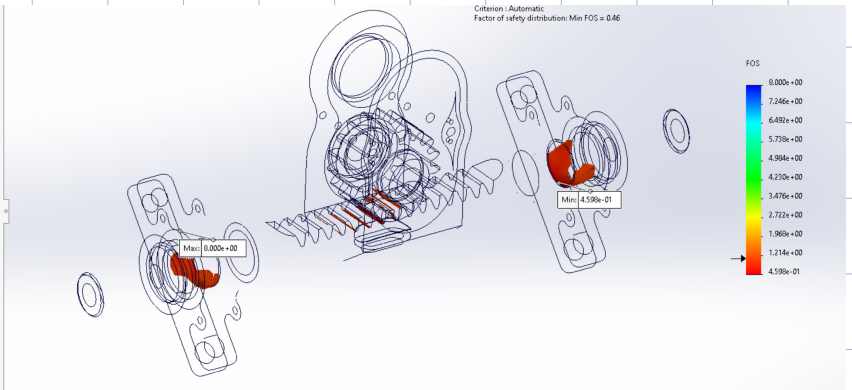


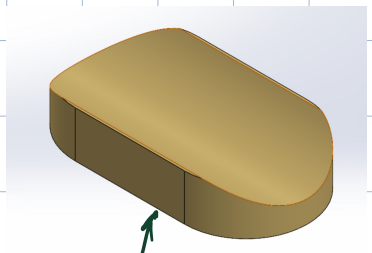


← wasn't able to run FEA (smth wrong w/ interactions...)

- circle pillow block... 
  - → might not be the most accurate bc tolerances

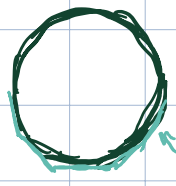






not really machinable...

- multiple pts of contact (>2)



multiple pts of contact
(not possible, no endmill small enough)

To-Do

- figure out pillow block/housing design
- FEA for full-steer wheel bump
- review machinability w/ Jaffer

1/25/24

1/31/24

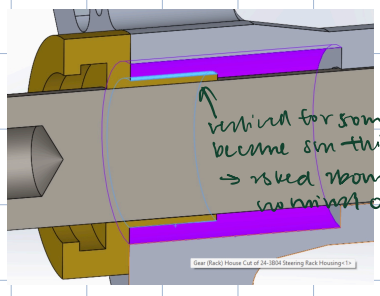
Setup overview w/ Ian

- realized a contact interaction was missing btwn bottom of pillow block and top of SRH shoulder
  - → no wonder why the rack was bending out of its mind like this:

  - → added interaction and results made a little more sense (low FOS on shock)

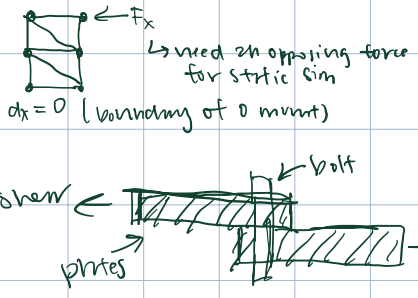
Tolerancing Brass Bushing and Housing

- check machining handbook
  - → different types of fits explained
    - → in this case, press fit (FN 2)
      - ↳ need enough friction force to keep bushings in place

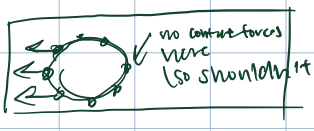


FEA Overview w/ Xavier

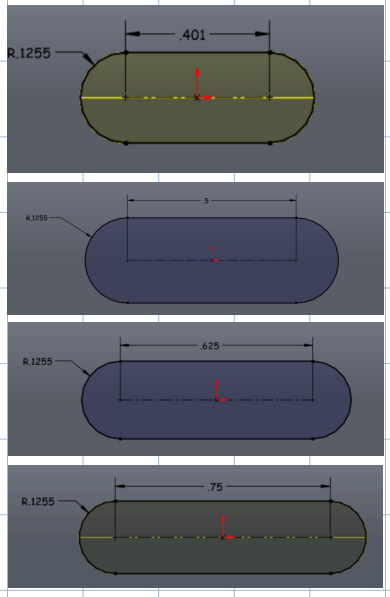
- nodes



nodes near each other on parts "connect" through local interactions



- one solution: increase pillow block SA bc same force over more area
  - → 0.18 FOS on pillow block... etc



0.2
1.1

0.3
1.1

tried... (.000")

- probably tried bc inadequate fixtures... 2/1/24
  - → changed bearing supports to fixed hinges...

2/4/24

let's try smth new!

- increase depth of pillow block (increase fillet radius)

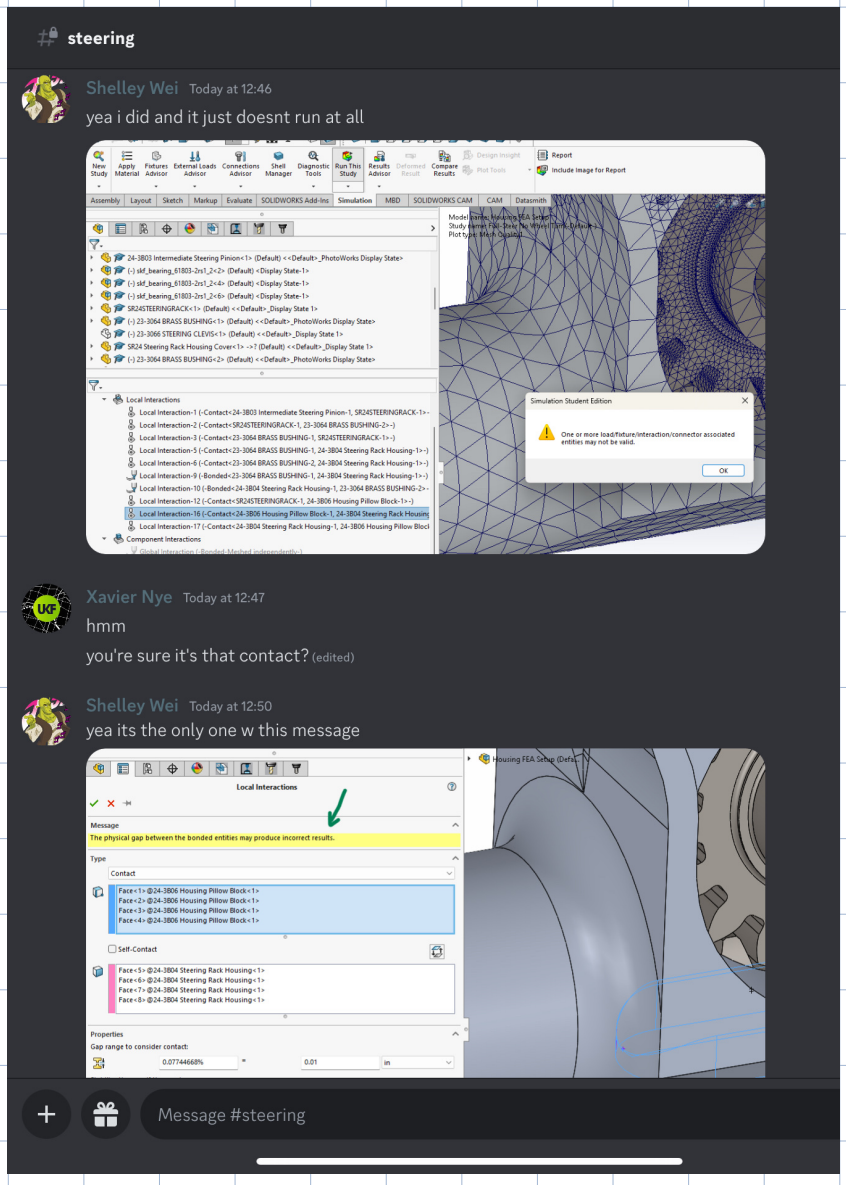
→ YIPPEE! 0.36 min FOS

→ Daniel reminded me that the 120° version still exists and that I should try that again

→ I don't exactly remember why I stopped testing that one

→ either be hard to machine to tolerance (what I wrote down above) or the sim failed

120° version



it just doesn't solve... 2/5/24

- one of the loads, fixtures, interactions, or connections are just wrong

→ but, when I run the exact same sim w/ the that pillow block, it solves...

THAT'S IT. I'm going tracking Ansys on this...

THAT'S IT. We're just sensing it. No more FEA! 2/5/24

NEVERMIND. More FEA (Jaffer) 2/6/24

- need to validate pinions themselves (they're already sent though...)

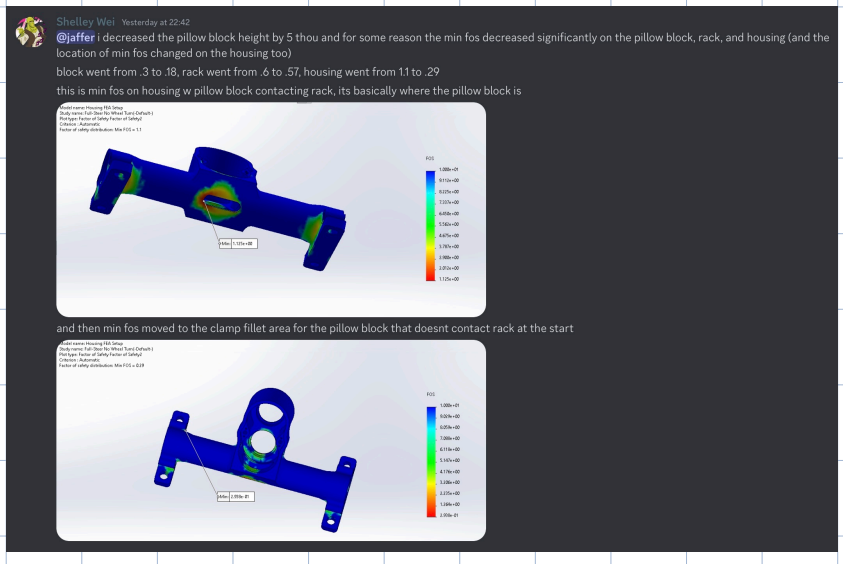
$$\text{torque arm} \quad \frac{1200 \text{ in lb}}{\frac{1.21 \text{ (pitch circle)}}{2}}$$

(apply to face of steering rack tooth)

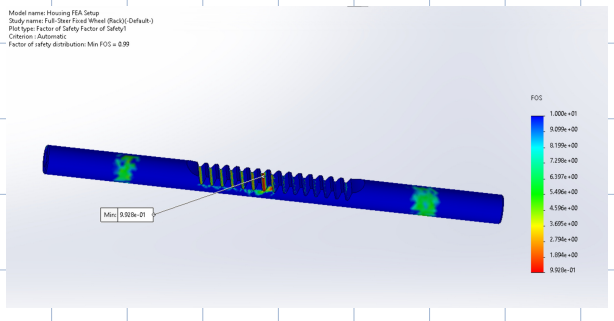
$\tau = rF\sin\theta$

- add some grip btwn pillow block (!!!)
  → bc rack might not be gripping yet

!!! wait...
  → min FOS went down on EVERYTHING
  → decreased pillow block height by 5 thou



- rack FEA w/ Ammar
  → sim w/ pillow block
  → split lines for bushing (or just activating part in bushings)
  → center of rack fixed
  → load: from ergo testing
    → 60 lbf from Brendan (NOT WFT data!)
  → remember to fixture everything! otherwise sim no run!
  → running
    → 1st time, min FOS was mid (-10 thou?)
    → 2nd time, tried w/ short PB
      and realized rack was displacing in the opposite of expected direction



→ ran it again and checked deformation w/ pinion

→ saw that pinion was spinning CCW instead of CW so basically we ran the sim entirely incorrectly

→ reversed the load to be CW

→ sim doesn't solve

→ "model may not have adequate fixtures"

→ used "Underconstrained Bodies" to check, but it calculated that the model is fully constrained so...

→ it seems like there are adequate fixtures...

→ next steps still:

→ axially

→ ~~tangentially~~ radially

→ ~~radially~~

→ circumferentially

→ ~~rotationally~~..?