Post - Critical Design Review

Front Shaft

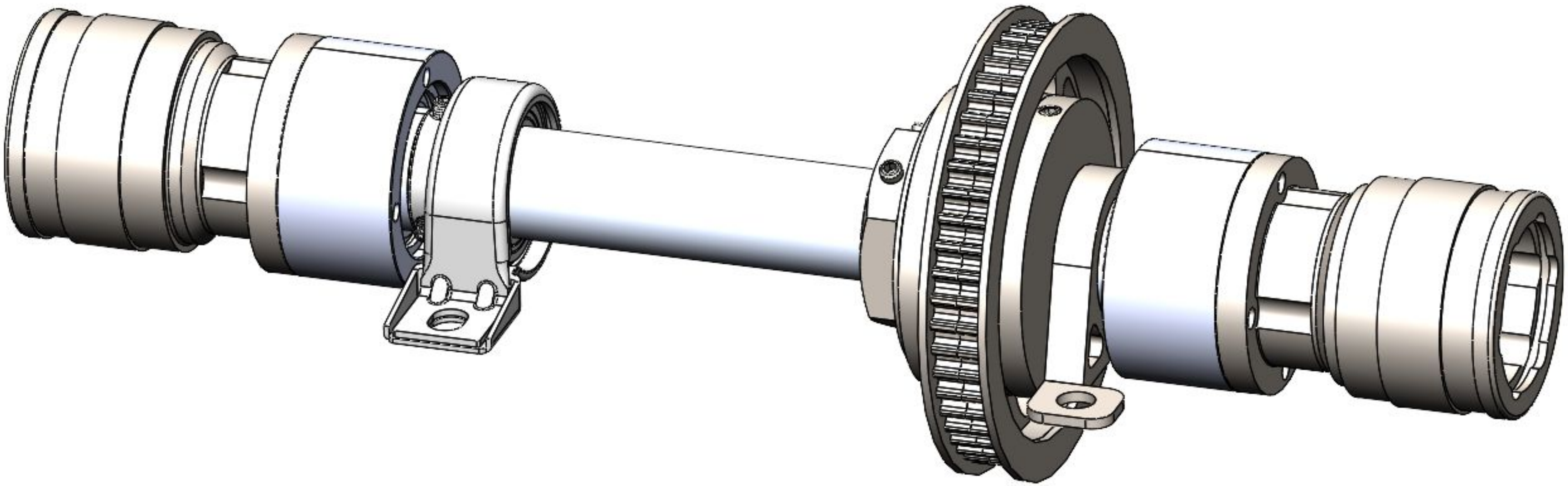
Shua Halle

Design Highlights

Integrated Clutches

Shaft weight: 0.8 lbs

Total weight: ~13 lbs



CDR Recap

- Determined that front clutches should be inboard
  - Reduces complexity of front hubs
    - No need to select multiple bearings to meet design requirements
  - Makes front hubs easier to install/remove, decreases pit time by minutes
    - Faster maintenance on the brakes and uprights, which are behind the hubs
  - Increases available space for clutches (stronger clutches can be selected)
  - Expected to reduce total weight of front powertrain
    - To be verified by comparing different design weights

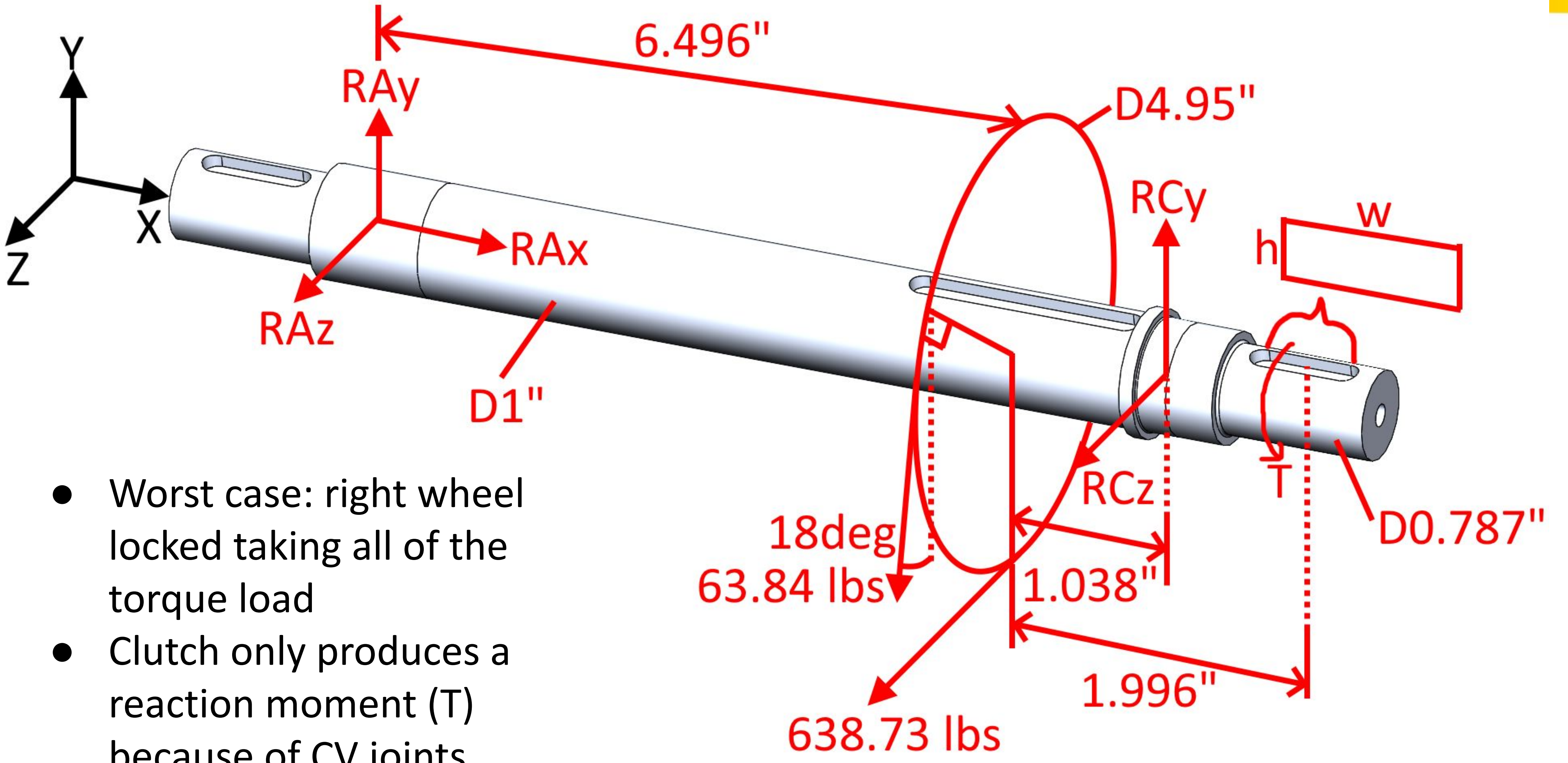
Clutch Selection

Sprag clutch selection limited by CV joint mounting strategy.

Stieber Clutch AA Series fits size and strength constraints:

- Axial mounting holes, facing towards CV joint
- 20mm inner diameter < 25.4mm shaft diameter
- Max torque: 215 lb-ft > 120 lb-ft

Shaft Calculations - Static Eq.



- Worst case: right wheel locked taking all of the torque load
- Clutch only produces a reaction moment (T) because of CV joints

Bearing and Keyway Reactions

T = 1422.9 lb-in

RAx = 61.23 (with 5 degrees of belt misalignment)

RAy = 8.365

RAz = -90.72

RCy = 52.35

RCz = -567.74

See MATLAB script in Kenesto folder "Calcs"

Internal Forces at Step

T = 1422.9 lb-in

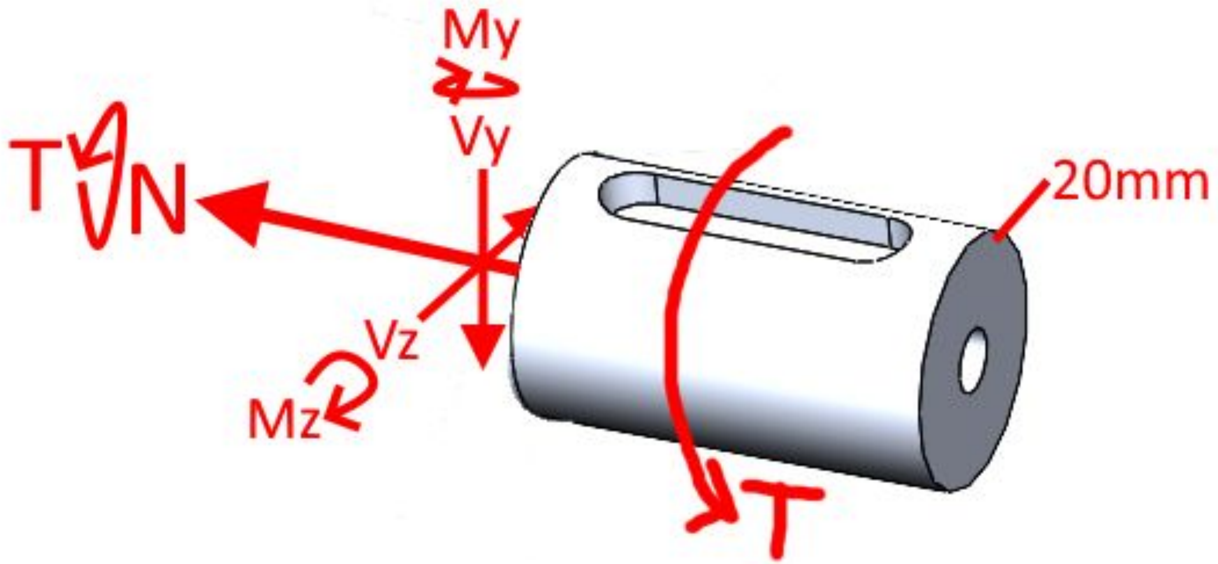
yield strength of 7075T6: 5.05e8 Pa

shear strength of 7075T6: 2.53e8 Pa

tau_xz = T*r/Ixx

Ixx = pi*d4/32

tau_xz = 1.0234e8 Pa → SF=2.47



Stress Concentrations at Step

Fillet radius matches the fillet on the clutch.

$D/d = 1.27$

$r_{fillet} = 0.01181102\text{in}$

$r_{fillet}/d = 0.015$

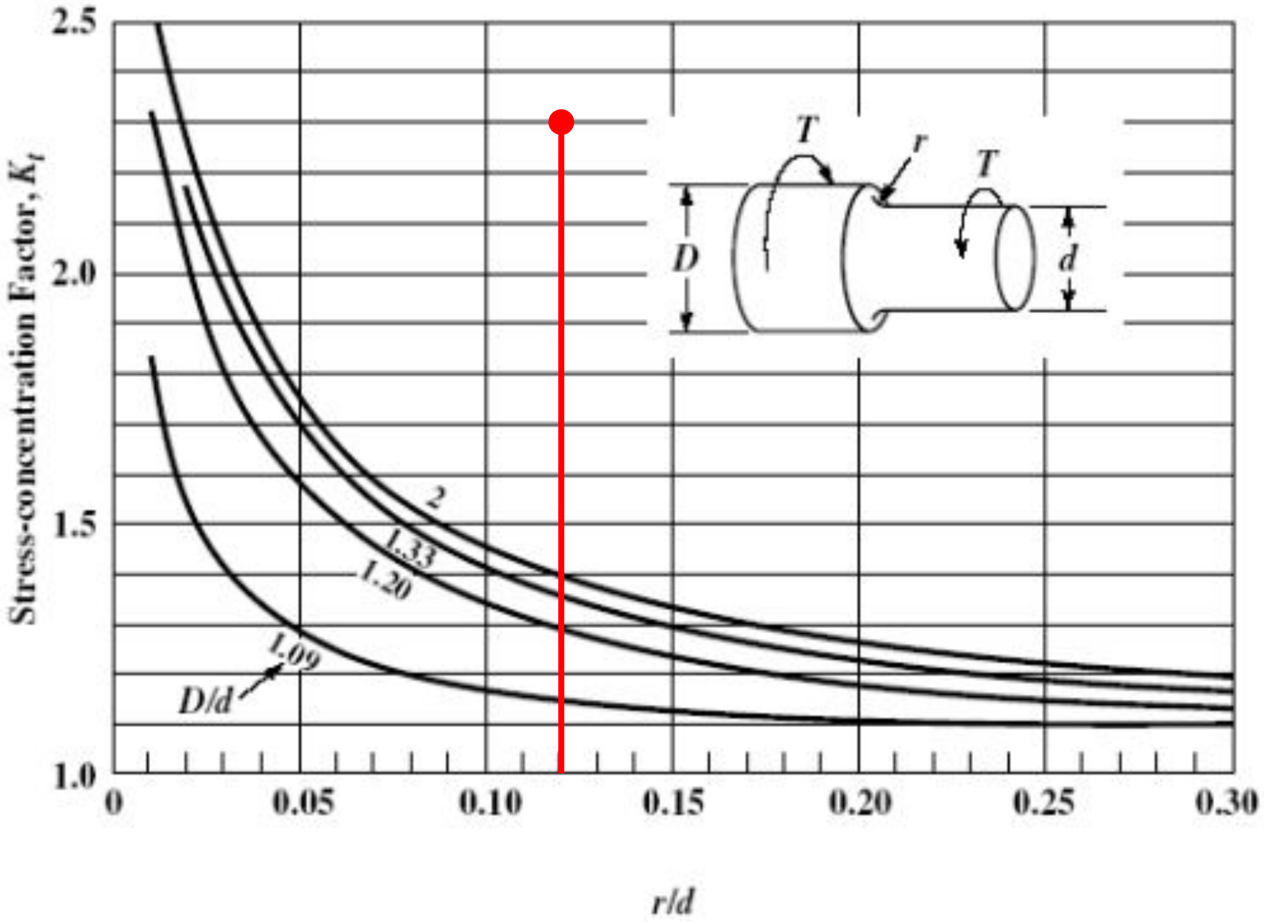
$K_t = 2.3$

$\text{tau\_xz} * K_t = 2.354\text{e}8$ Pa

SF = 1.0727 👀

Sys = Syt/2 is conservative.

SF = 1.24 using Sys = Syt/sqrt(3), which is less conservative.



Keyway Stress

Assuming force F is uniformly distributed across rectangular area of keyway:

w = 6mm

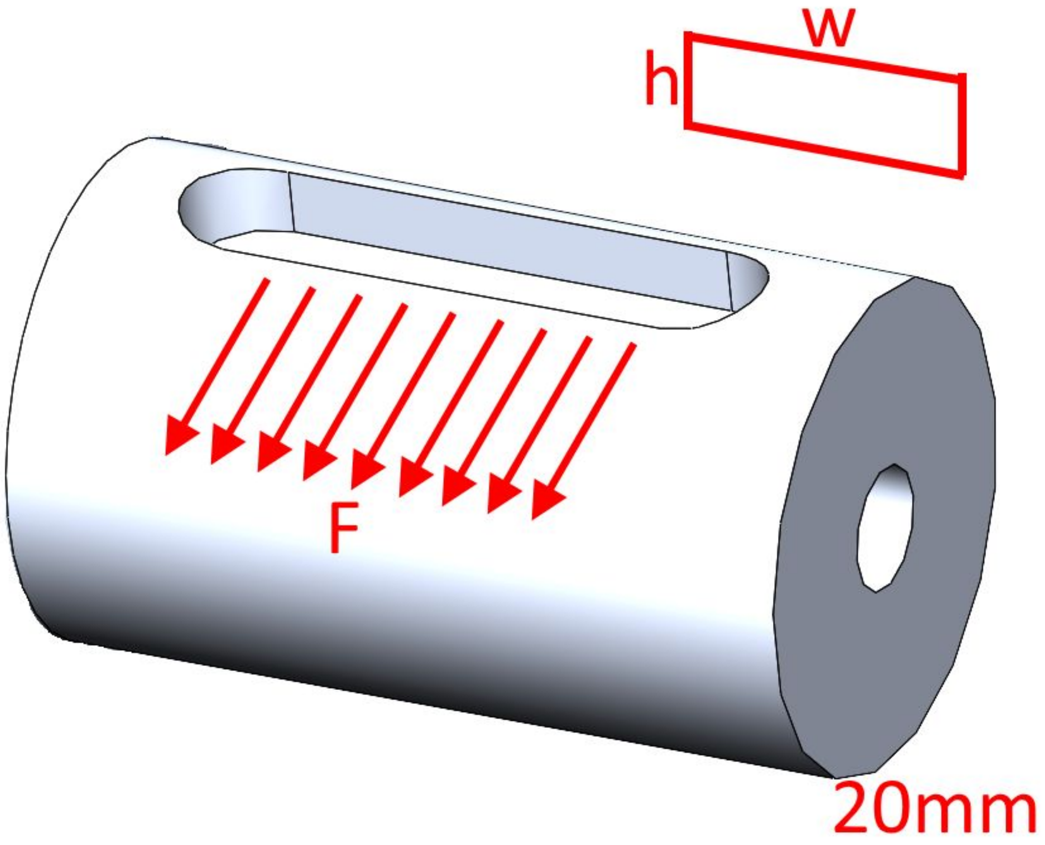
h = ~3mm

A = .08088756 in^2 (from CAD)

F = 120/(r-h/2)

sigma = F/A = 3.668e8 Pa

SF = Syt/sigma = 1.37



Bearing Selection

Constraints:

- ID <= 1 in, ideally would be as close to 1 in as possible
- Width < 0.4in
  - (gap between shaft stop and clutch) - (width for bearing housing) - (height of 1/4-20 bolt head)
- OD < 5 in (~diameter of front pulley)
- “Static” radial load > 855.23 lbf
  - SF*sqrt(RCy2 + RCz2) = 1.5 * 570.15 lbf = 855.23
- Max rpm > 507 rpm (from powertrain flowchart)

Minimize

- Weight

Best Option

SKF 61905-2RZ

✅ ID = 0.984 in < 1 in & ~= 1 in

✅ OD = 1.654 in < 5 in

✅ Width = 0.354 in < 0.4 in

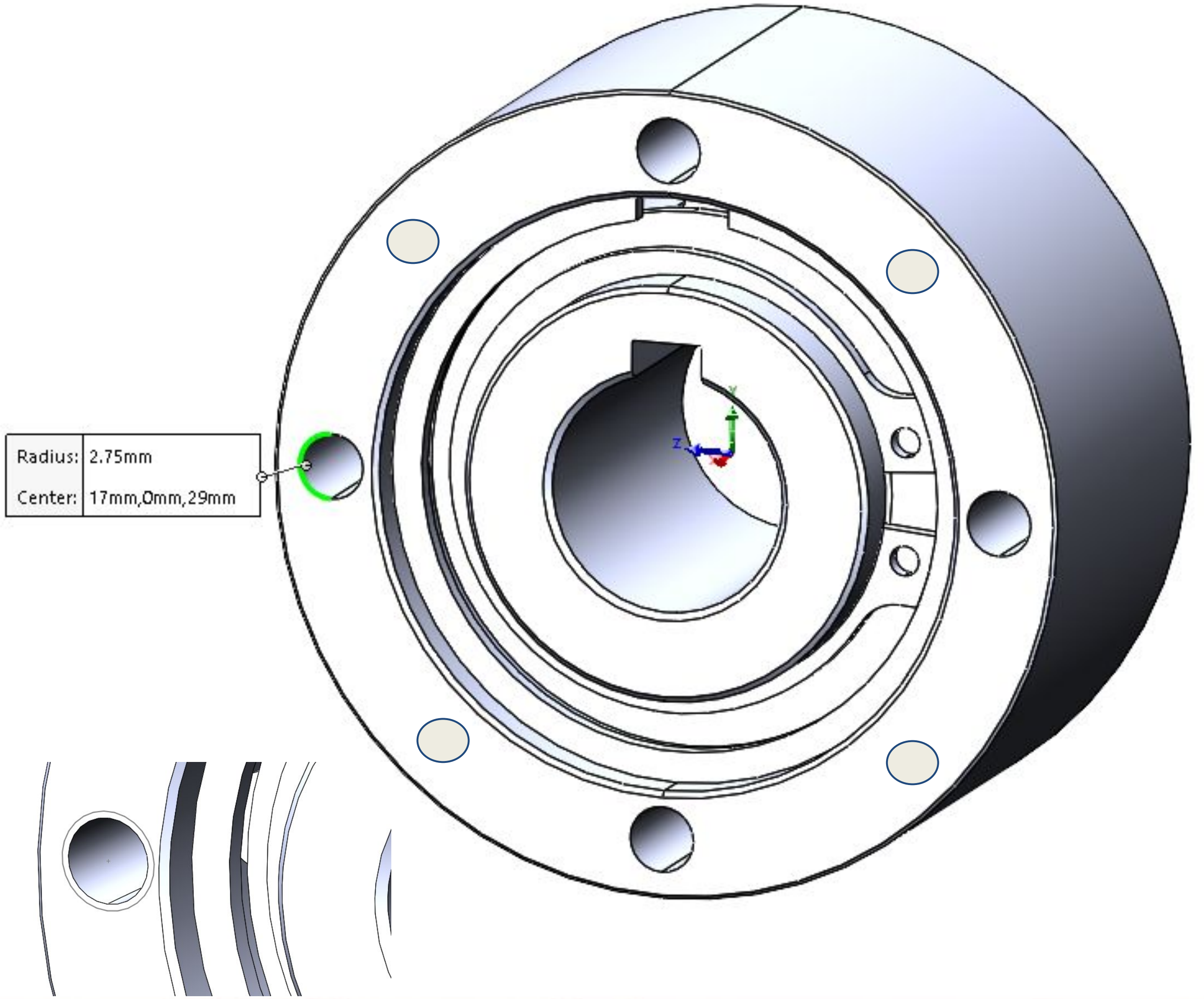
✅ Static load rating = 967 lbf > 570.15 lbf

✅ Limiting speed = 18000 rpm > 507 rpm

✅ Weight = 0.1 lb

One More Thing About The Clutches™

- Hole diameter is 5.5mm (0.22”)
- What happens if we just drill to make them into 1/4” through-holes?
- Then, we are left with a cross-sectional area of: .03248” x 1.3” = 0.04222 in^2 between the bolt holes and the inner race
- F = 1416 lbf due to torque at that location
- Assuming all that force goes through that small area, the pressure is
- P = 33542 psi = 231.3 MPa
- Yield strength of 4130 steel = 460 MPa
- SF = 1.9, so we can do it (carefully)



Conclusions from Theoretical Analysis

- All safety factors are above 1 👍 (but…)

SF_{step}=1.07, $SF_{step,cheating}$=1.24, SF_{keyway}=1.37

- Stress concentration at step is very close to failing in the conservative case, and has SF<1.5 in the non-conservative case
- Safety factor at the keyway is also below 1.5
- It is unlikely that the shaft sees loads beyond the 120 lb-ft of torque because of the torque limiter, so there is justification to reduce the safety factor target below 1.5 to 1.25
    - We can also reduce the torque limit to reduce risk

So, the shaft works in theory, barely.
But wait, there's more!

Interfacing…

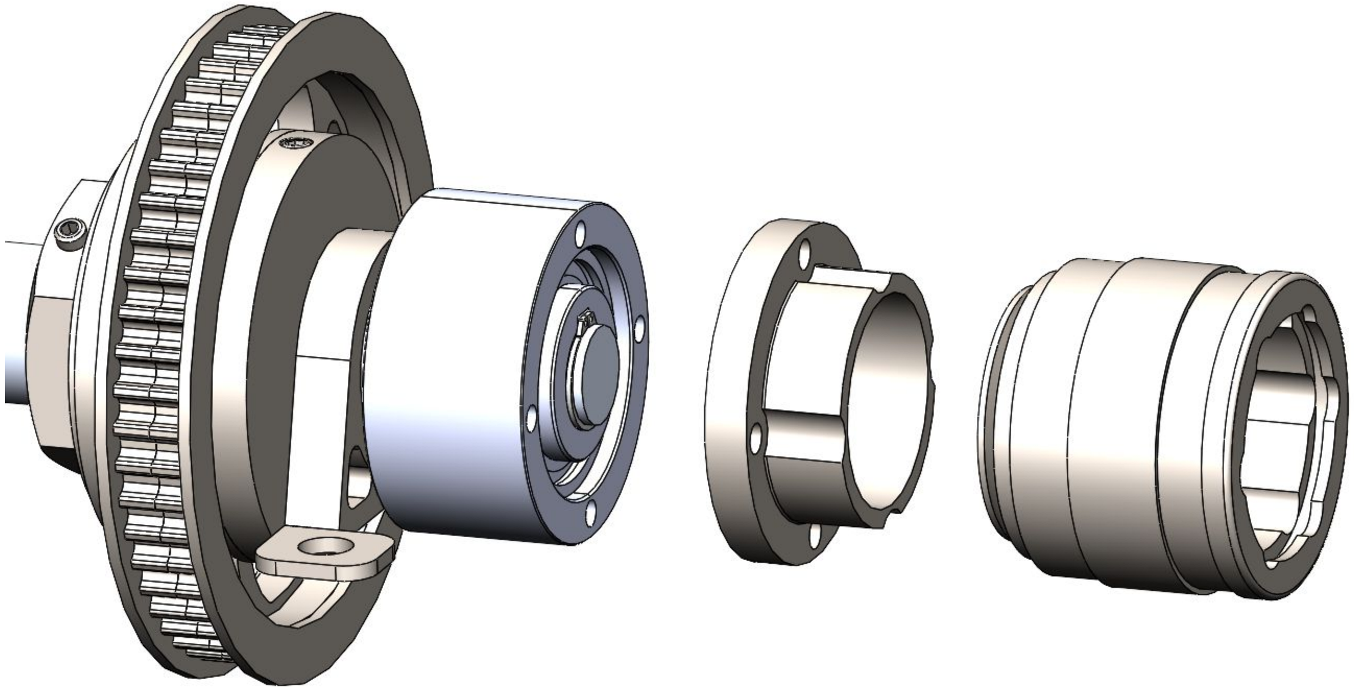
Connecting to the IJs

Using 2” long 1/4-20 bolts through the sprag clutch, with lock nuts fitting onto the other side of the spacer block.

- Coarse threads reduce assembly/disassembly time

The IJs are cut to have a flush base, then welded to the spacer block.

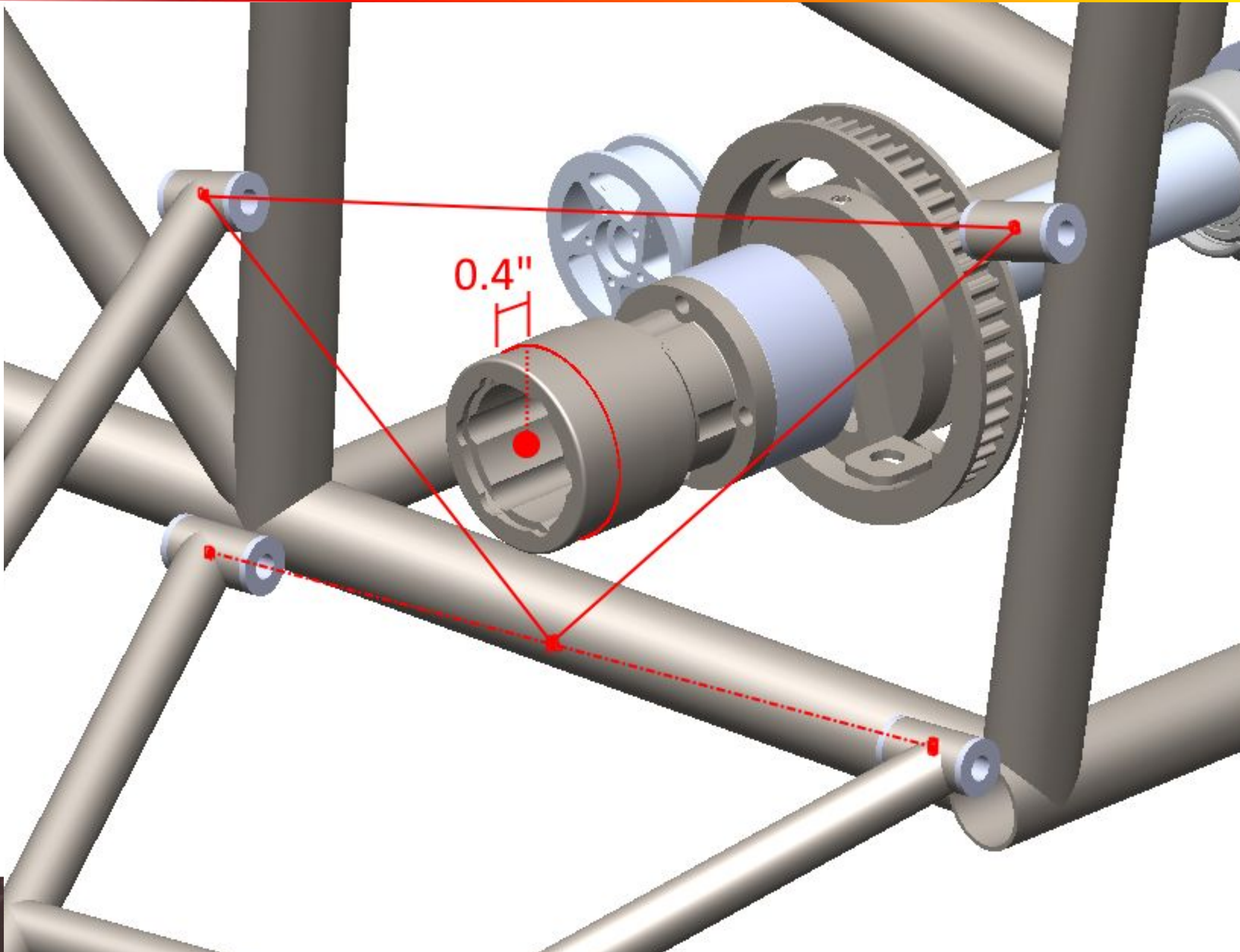
Bolts must be tightened with wrenches because there’s no space



Finding the Right Spacing

Keeping center of IJ rotation that minimizes binding (~0.4 from face) in-plane with the suspension arm pivot plane.

Used math to solve for the correct distance (see speaker notes).



CAD Review (see Kenesto)