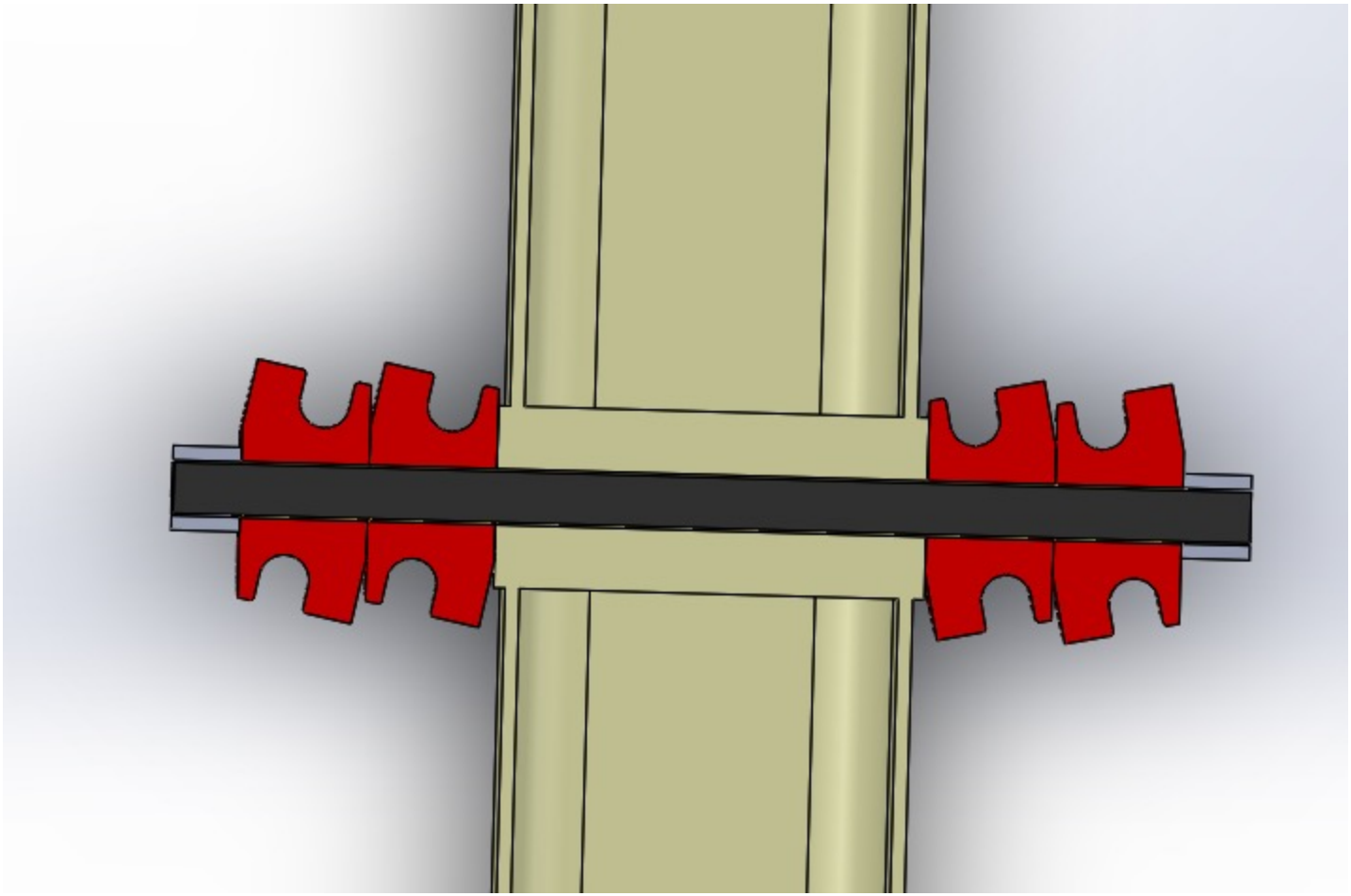
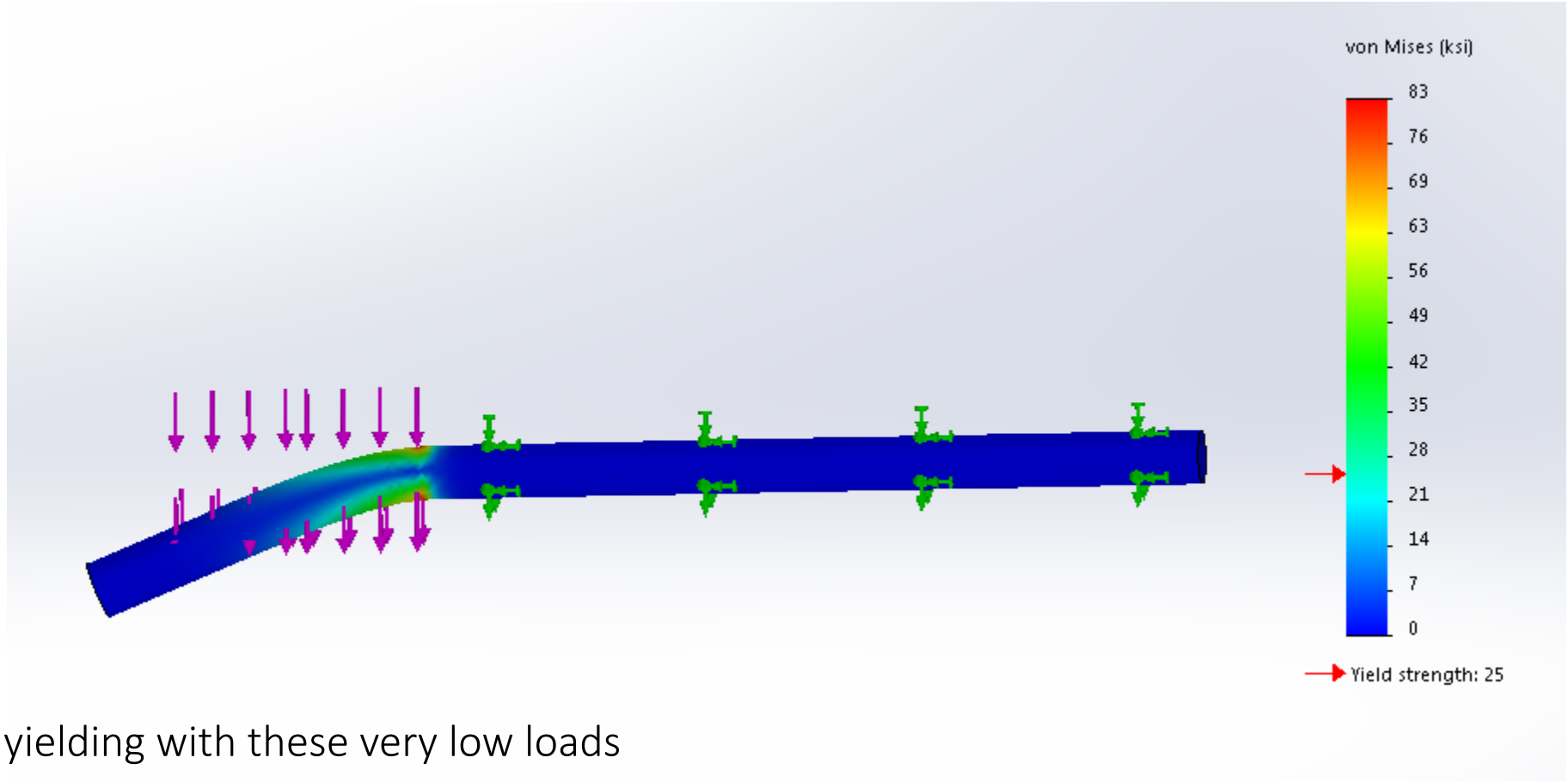
Original assembly cross section for reference showing mast, compression tube, threaded rod, nut on each end, cheeky tangs



First will analyze the threaded rod (aka bolt) and then the rest of the assembly with increasing detail as needed

Simulating threaded rod on left side only
500 pounds “down” over each cheeky tang section (x2 = 1000 pounds total), rod fixed along surface that’s inside mast



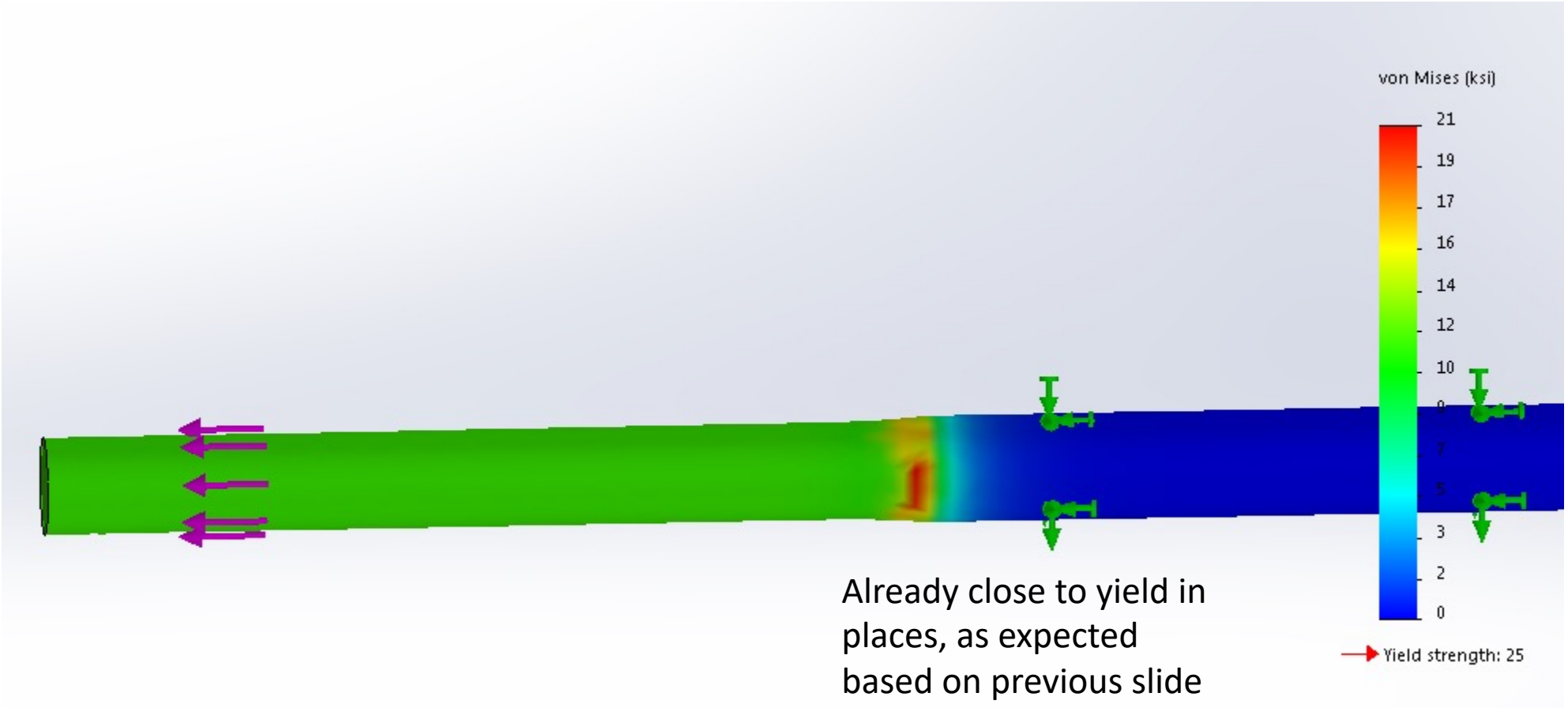
Already yielding with these very low loads

A Grade 2 bolt

- 57ksi tensile strength (roughly double the stainless)
- Recommended torque is 50 or so foot pounds
- Clamp load around 6100 pounds

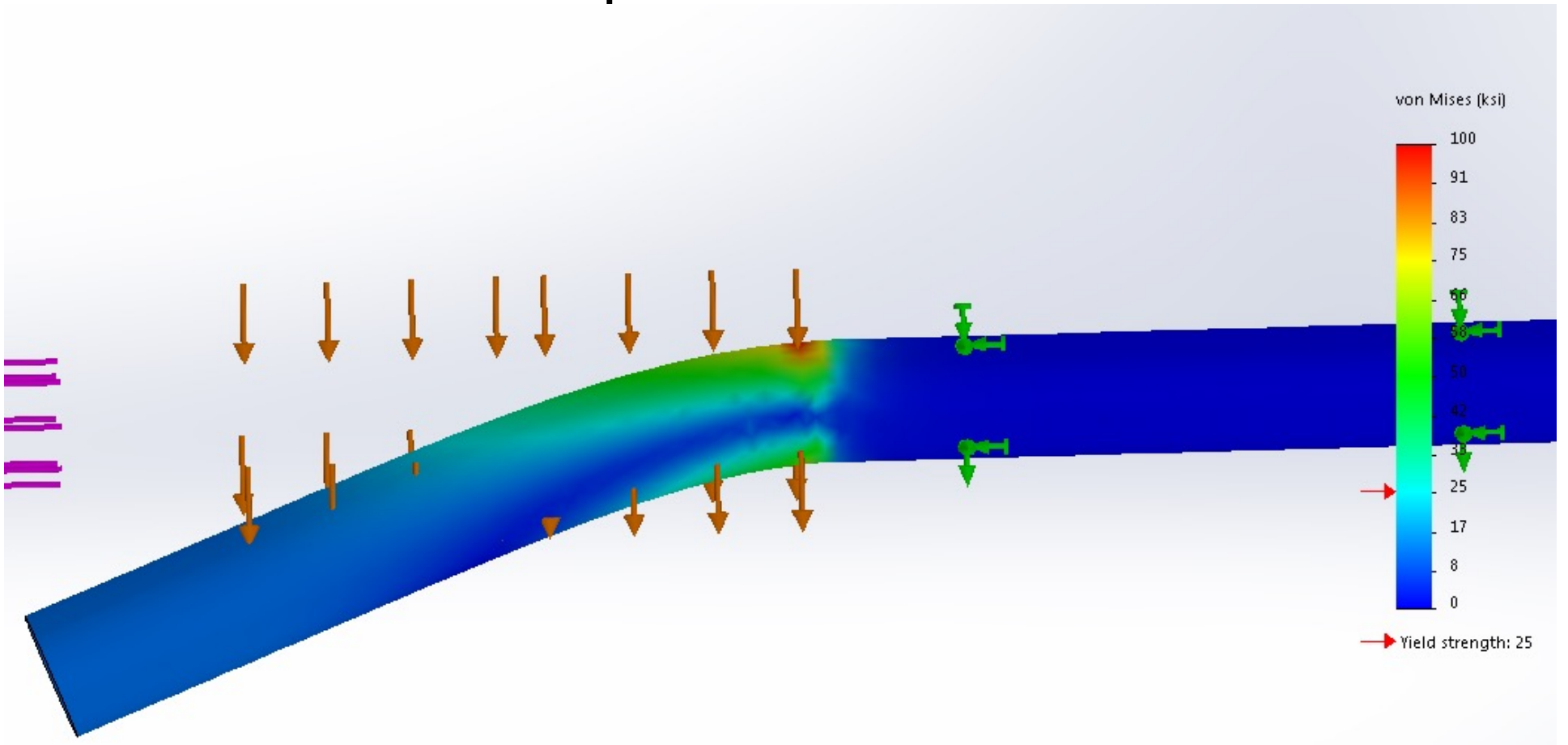
- Stainless is a lot weaker, roughly half the strength of Grade 2. I torqued much higher, meaning I most likely yielded the threaded rod on initial assembly

3,000 pounds of tension to threaded rod, no other loads



Already close to yield in places, as expected based on previous slide

Above tension plus above shroud forces

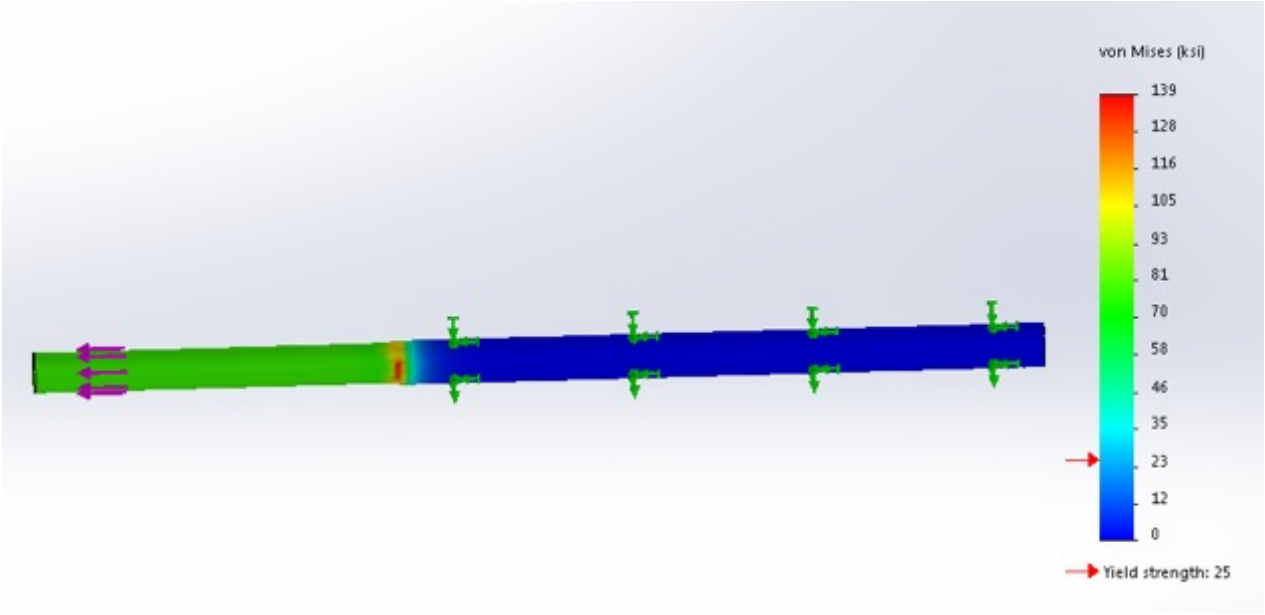


Conclusion: Tension in the bolt from tightening it makes stress higher, in this simple scenario, where the bolt acts as a pin to support the shroud loads, than a case where the bolt is left loose. Interesting..

How much pre-load is needed to prevent sliding of the cheeky tangs?

- Coefficient of friction for anodized aluminum on painted aluminum, guessing 0.5 (?)
- True shroud loads estimated to be <5,000 pounds each (5x the static tension)
- So, 20,000 pounds min clamping load desired

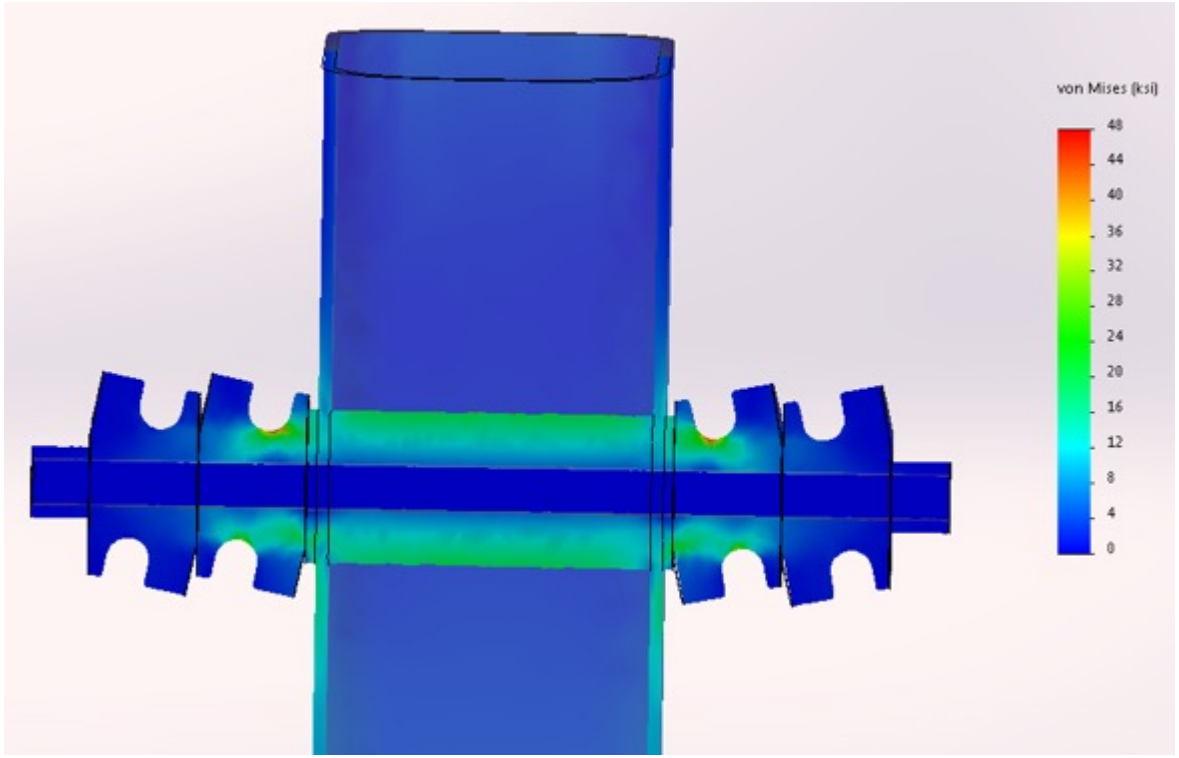
These loads applied to the threaded rod:

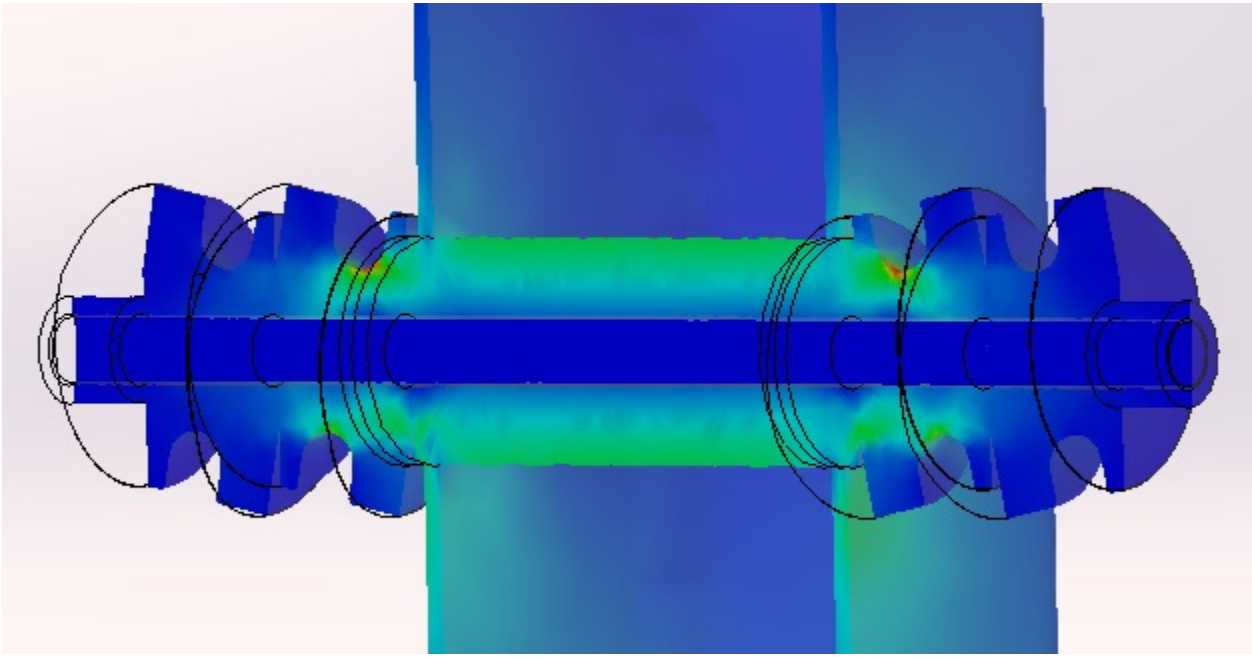


Conclusion: Using the bolt as a pin is unviable with 316 SS, which yields at <30ksi. Off by a factor of 5. With a grade 8 bolt, which has minimum yield of 150ksi, it is borderline, too close for comfort, but maybe ok if it isn't threaded in the high bending area (custom bolt). No threads were included in this analysis and they are stress risers if present.

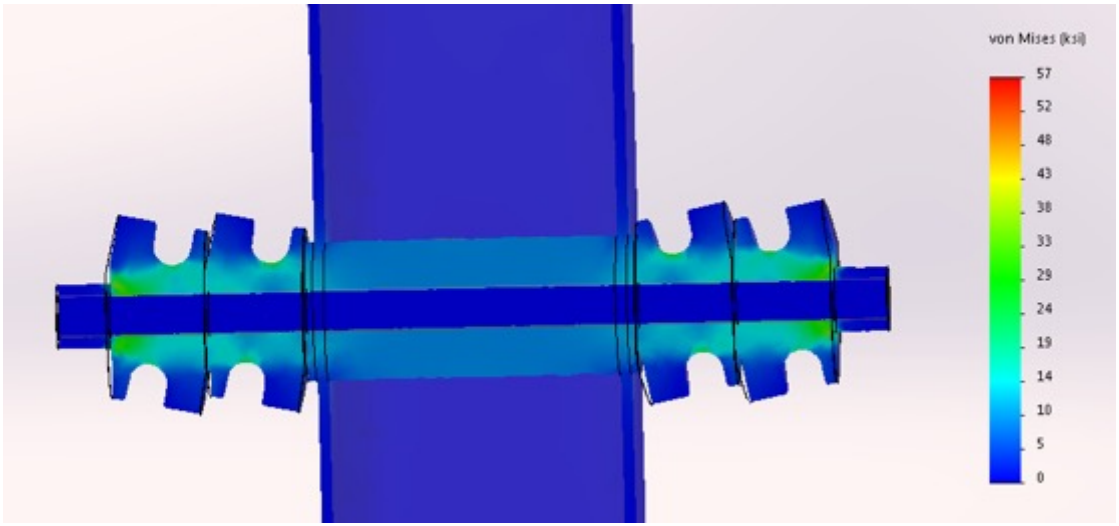
Now including other components in simplified form

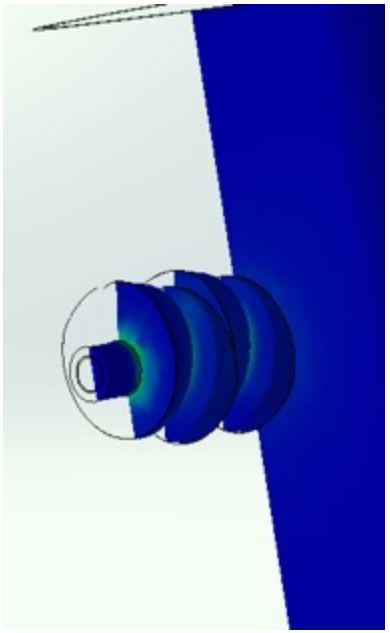
5k lb shroud loads only applied to a fully bonded assembly, no bolt pre-load

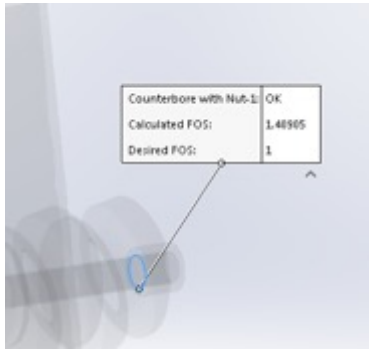




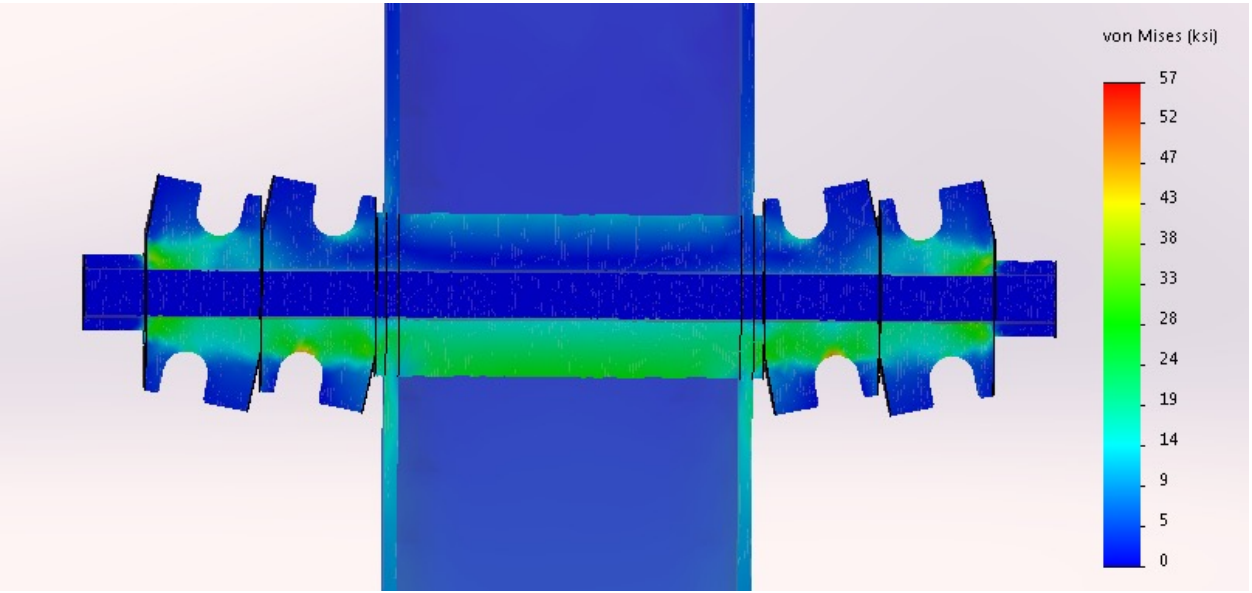
250 foot pound clamp load only applied to a fully bonded assembly

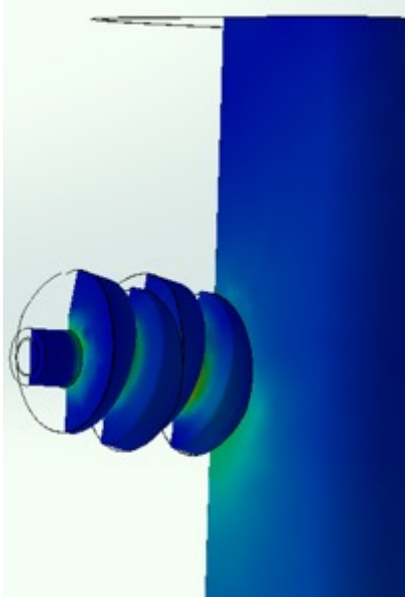


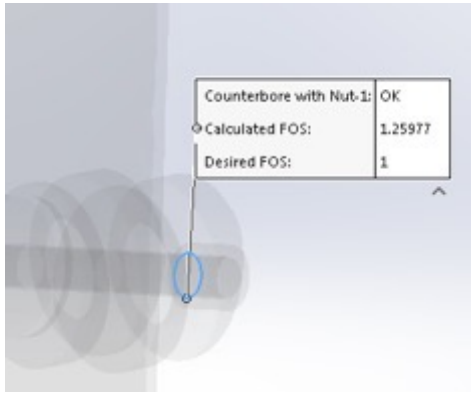




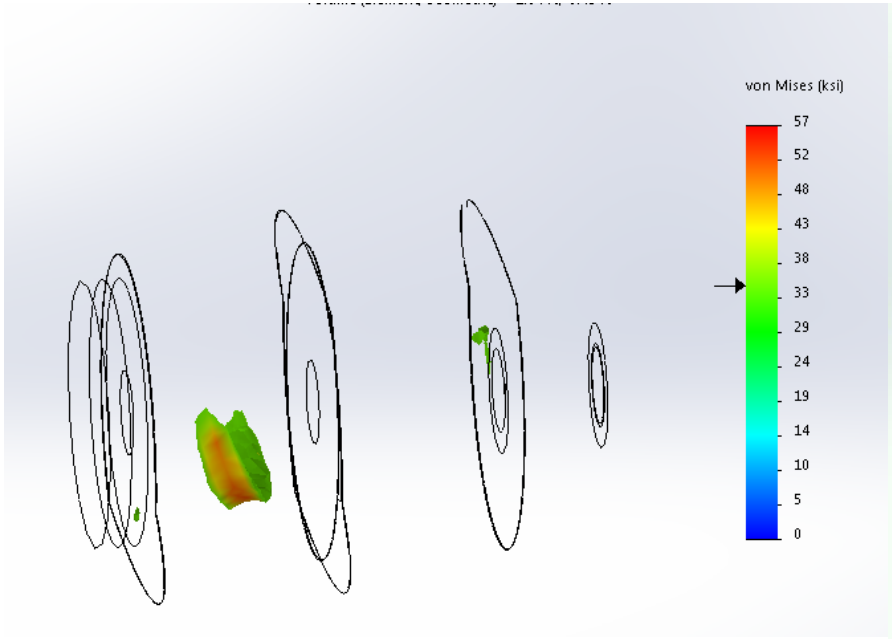
Clamp load and shroud load applied to fully bonded assembly

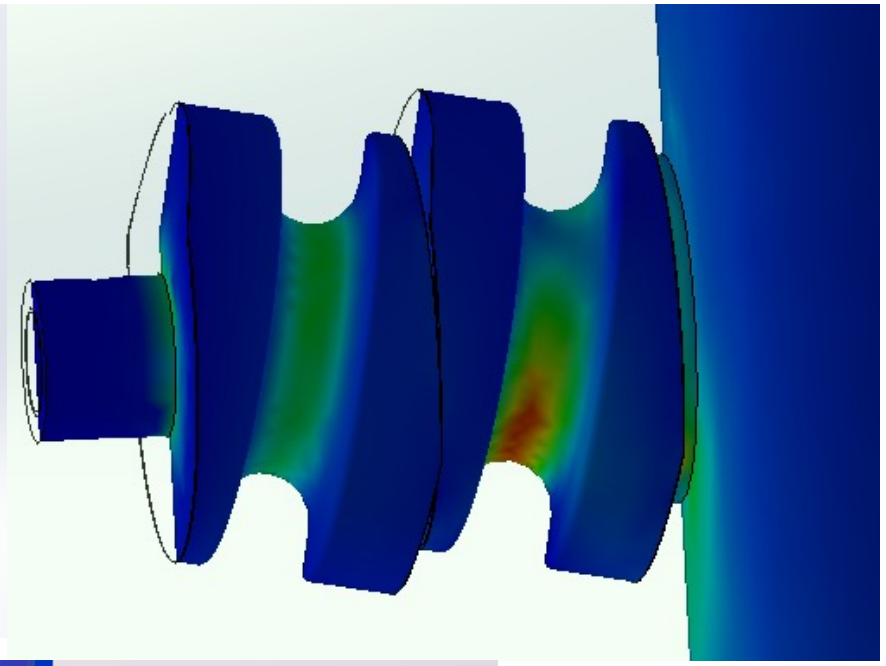




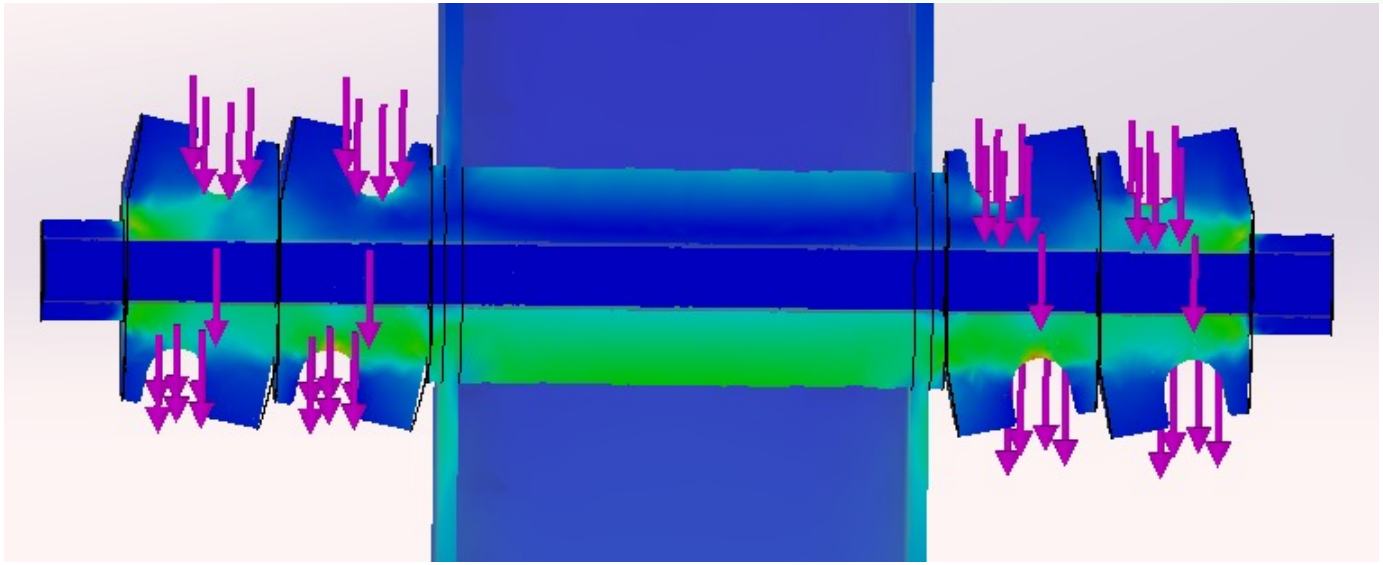


Zooming in on the last result





Small areas predicted to yield in the cheeky tangs, possibly related to the unrealistic bonding between components and/or the unrealistic way I applied the 5000 pounds to each shroud “bearing surface” for lack of an easy alternative. Not concerning yet but needs more thought later



No yielding in mast or compression tube, but, compression tube would clearly be better if it were asymmetrical to provide more support below the threaded rod, where all the stress is. These are fatigue loads, with unknown accumulation, so want best safety factor reasonably possible in all components

Threaded rod

- 250 foot pounds on grade 8 5/16-11 threaded rod makes 27,000lbs of clamping load. This is > than the 20k desired and validates the “bonded” assumption of the previous simulations
- Predicted safety factor on the bolt is 1.26, and I don’t have a cheap alternative to improve it at this time

- It looks like the original design would have worked, with 250 foot pounds of torque and a grade 8 threaded rod. The tangs would not have slipped, and bolt would not have had to act as a pin by itself in bending

- But now the mast is compromised, and a repair needs to make it stronger than it was

10-32 screws

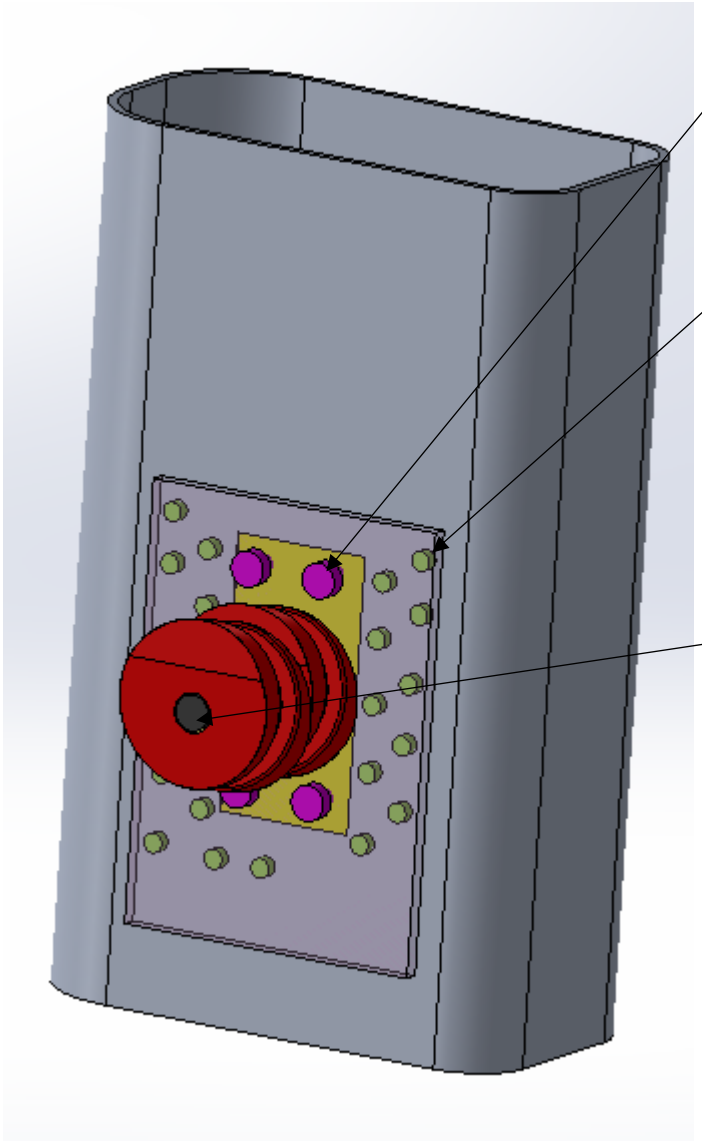
- 316 stainless recommended torque 33 inch pounds
- 820 pounds of clamp load
- To get to 27,000 pounds, I need 32 screws

- Grade 8 torque is 68 inch pounds
- 1800 pounds of clamp load
- To get to 27,000 pounds, I need 15 screws

- Cross sectional area = .020
- To get to .226 in^1, I need 12 screws

3/8-16 screws

- Grade 8 has 7000 pounds clamping load
- Need min 4 bolts to get required clamping load


3/8-16
bolts (4)
10-32 bolts
(at least 15,
pattern
TBD)
5/8-11
bolt (1)