Bottom CRU Installation:

Bottom Support Design and CRU Structural Modeling

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January 9th, 2025

Update overview

- New bottom support design: adjustable sliding on membrane floor supports for CRU
- Stress in the CRU: effect of differing adapter plate material and thickness

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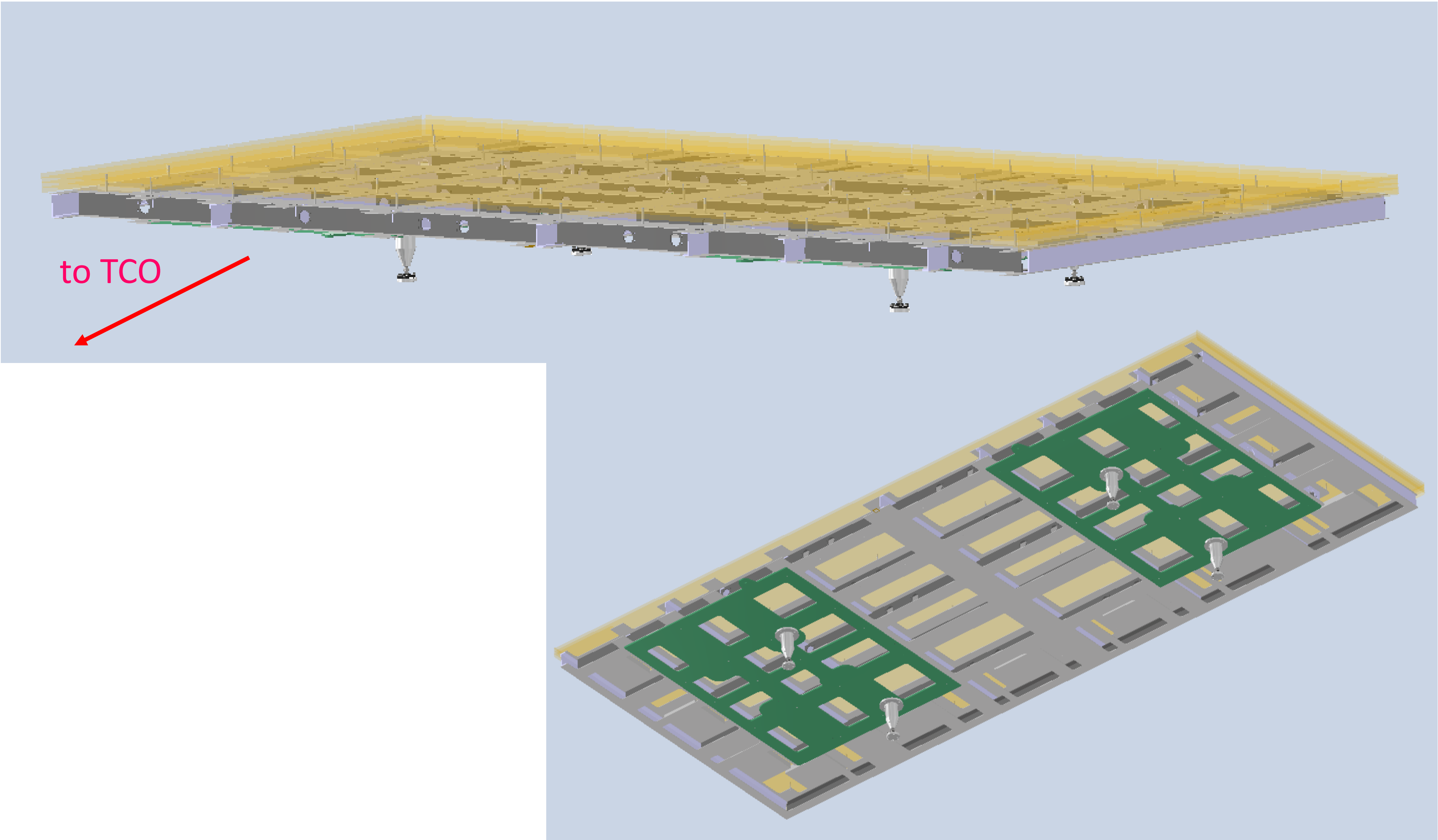
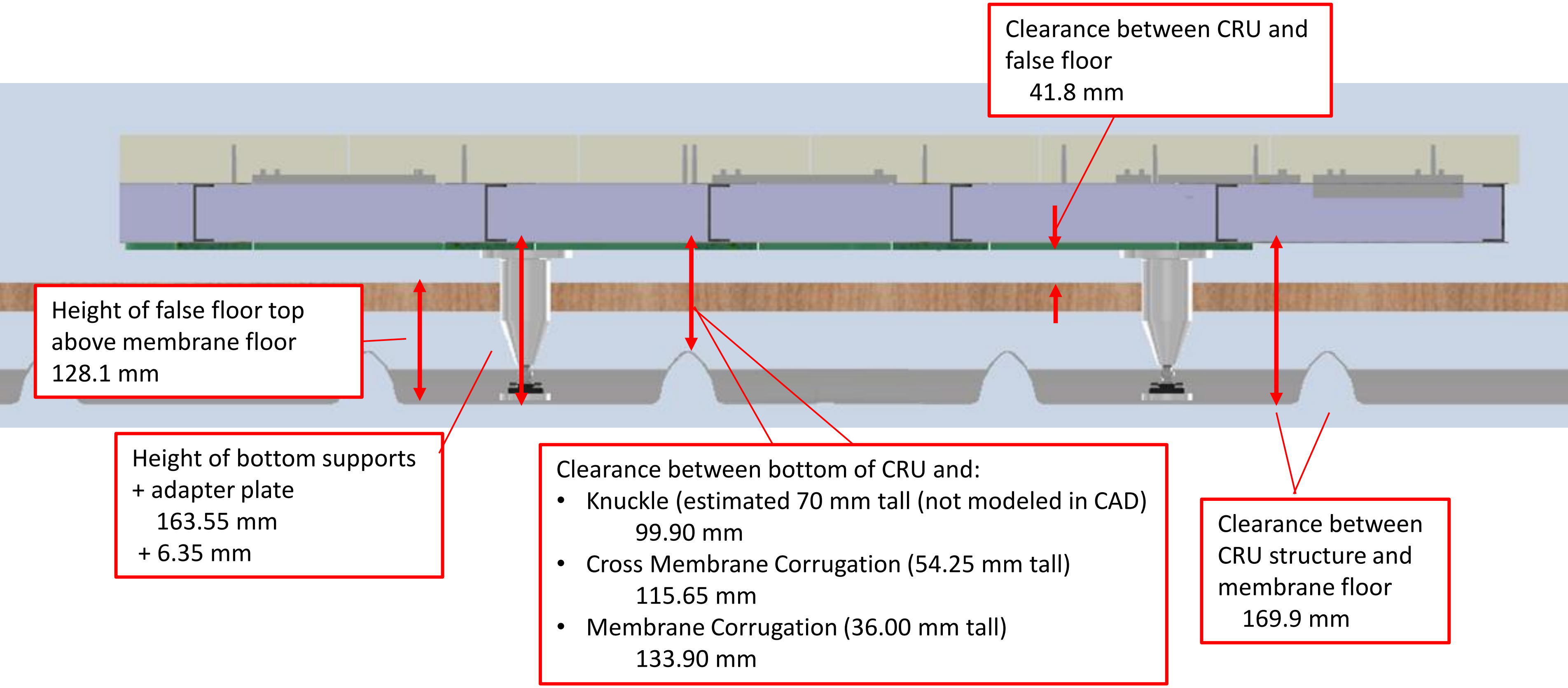
Bottom CRU Supports

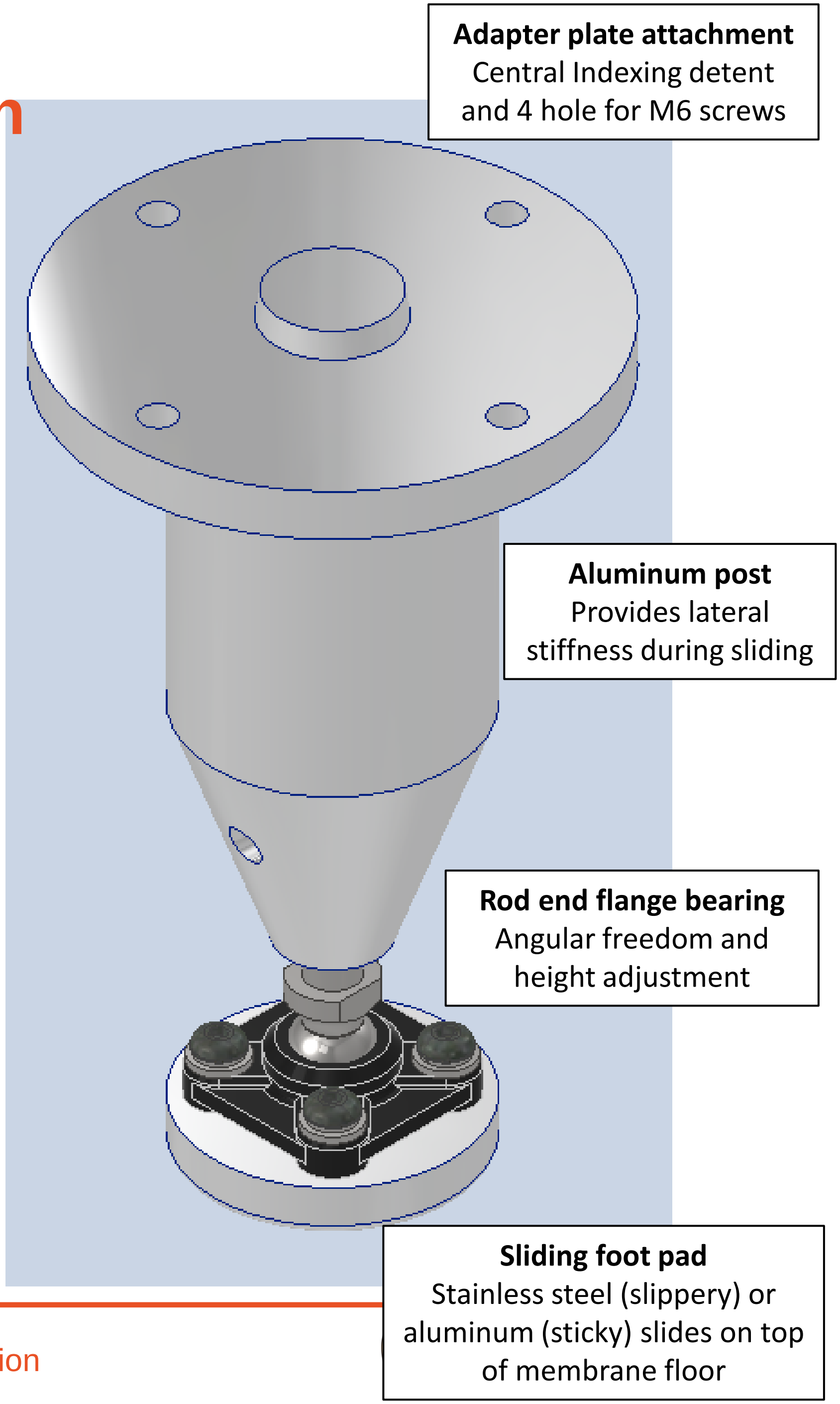


New FD Bottom Layout (up 20mm)



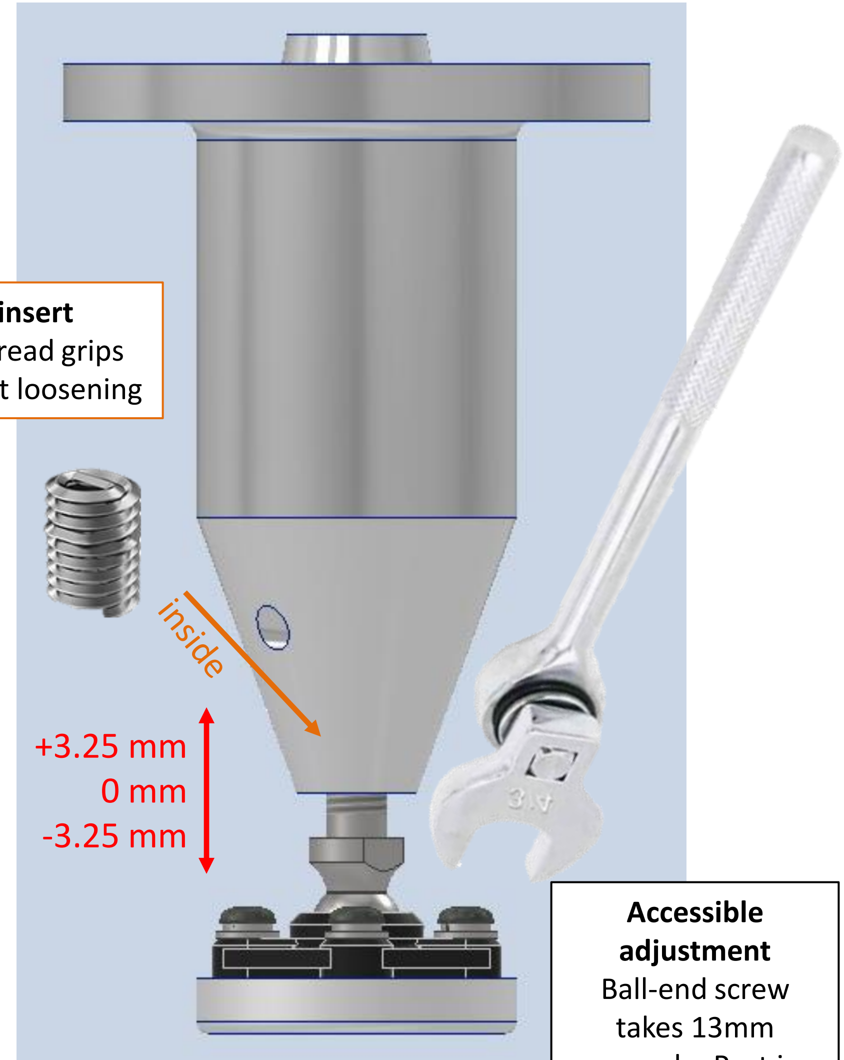
Bottom Support Design Function

- Simple attachment to adapter plate after unboxing and before flipping of CRU
- Sturdy design reduces deflection of CRU
  - thermal contraction at CRU transferred to sliding of pads at membrane floor
  - transfers shear force with minimal deflection and torsion on CRU
- Compliance with out-of-level membrane floor.
  - Ball connection for angular variation in floor.
  - In place height adjustment of 7.5 mm to allow leveling of CRUs.
- Gas relief prevents trapped bubbles, using designed relief features and hardware



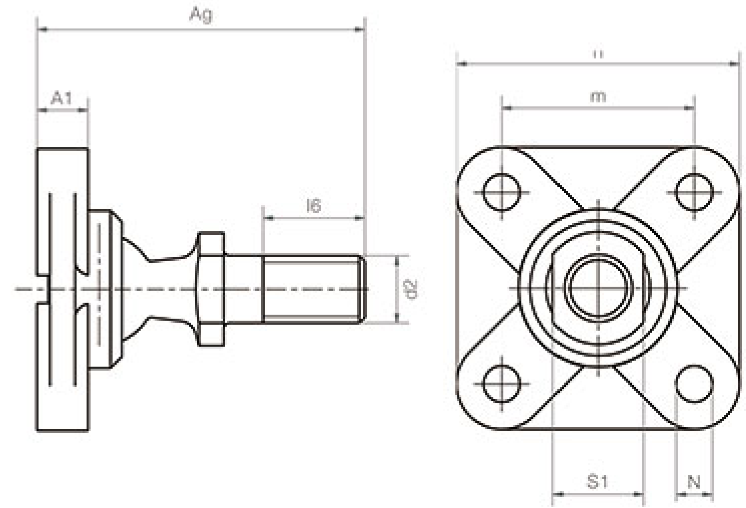
Height adjustment and leveling

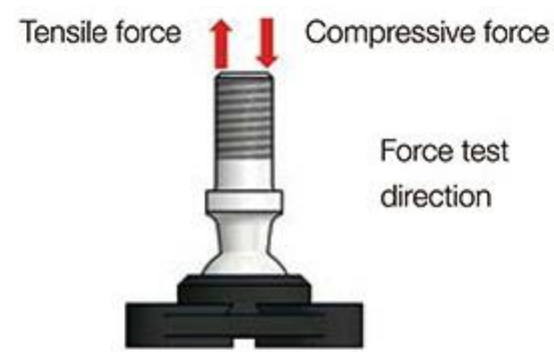
- 1st level/adjust CRU while placed on false floor. 2nd level/adjust corrections once CRU is placed on membrane floor.
- Screw for height adjustment
  - 7.5 mm total adjustment (5 turns)
  - M10x1.5 threaded stainless steel rod with 16mm of threads
  - Post contains screw-locking helical insert, prevents loose rotation of screw
- Adjustment can be performed after CRU is placed on membrane floor
  - Ball connection for angular variation in floor.
  - In place height adjustment of 7.5 mm to allow leveling of CRUs.



Flange Bearing

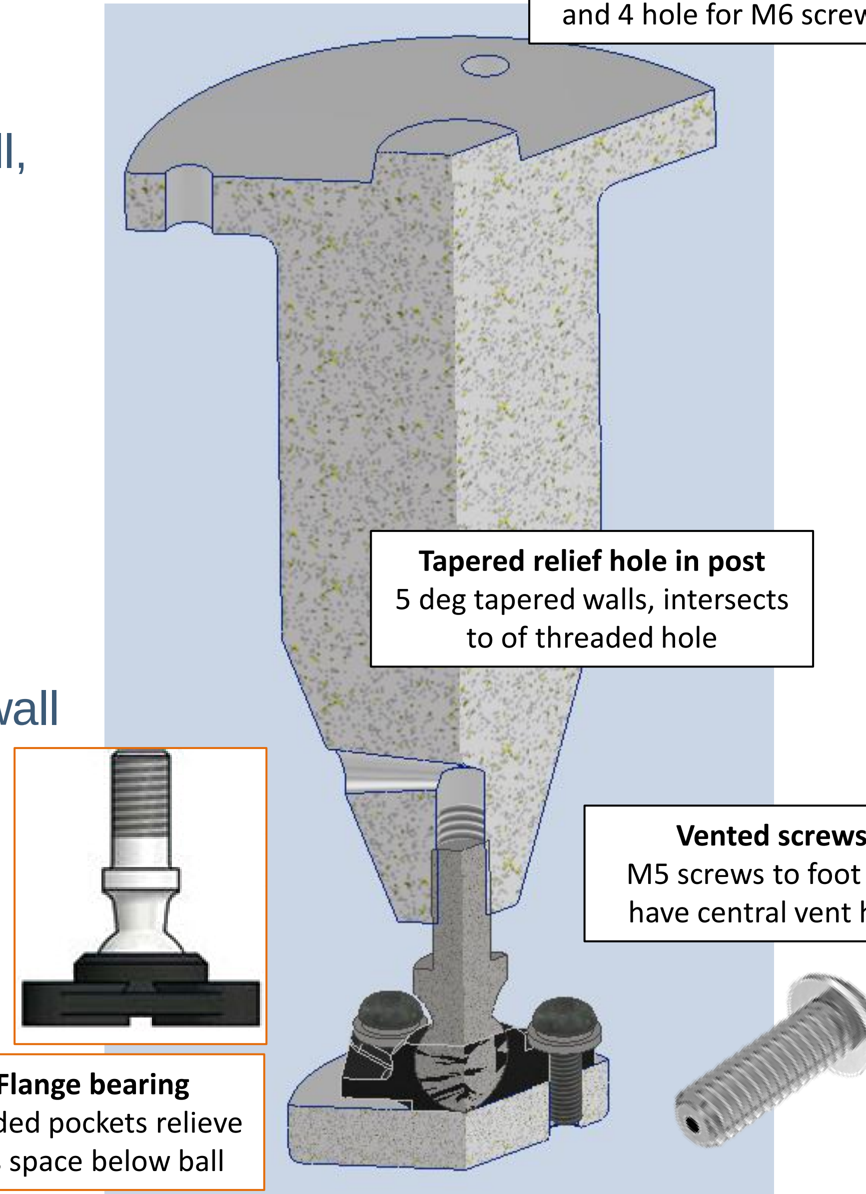
- Stainless steel ball-end screw gives 40deg max pivot
- Dry bearing. No lubrication of ball-end.
- Bearing pad out of igumid® G fiber reinforced polymer. Need to check compatibility with LAr. Manufacturer says suitable for "long term use -30 to 80C".
- Max static compression load:
  - 600 N (61 kg) long term -> 244 kg max per CRU
  - 1200 N (122 kg) short term -> 488 kg max dynamic load during CRU install
- Max static tensile load:
  - 70 N (7.1 kg) long term
  - 140 N (14.3 kg) short term
  - We can't lift the CRU by these bearings.





Gas relief

- Prevents trapped bubbles during LAr fill, using designed relief features and hardware
- Flange bearing features molded plater with relief below the ball
- Vented M5 screws prevent gas being trapped with the pad.
- Relief hole in post is machined using tapered end mill, giving 5 deg sloping wall for release of screw hole dead space.



Next steps

- Prototype 3 bottom supports. Produce both Aluminum and Stainless steel pads. Test pad on membrane floor sliding in our LN component sliding test system.
- Estimate FD production cost for 160 CRUs (640 total supports)
- Update CERN team with adapter plate and bottom support design for 2 CRU cold box test.

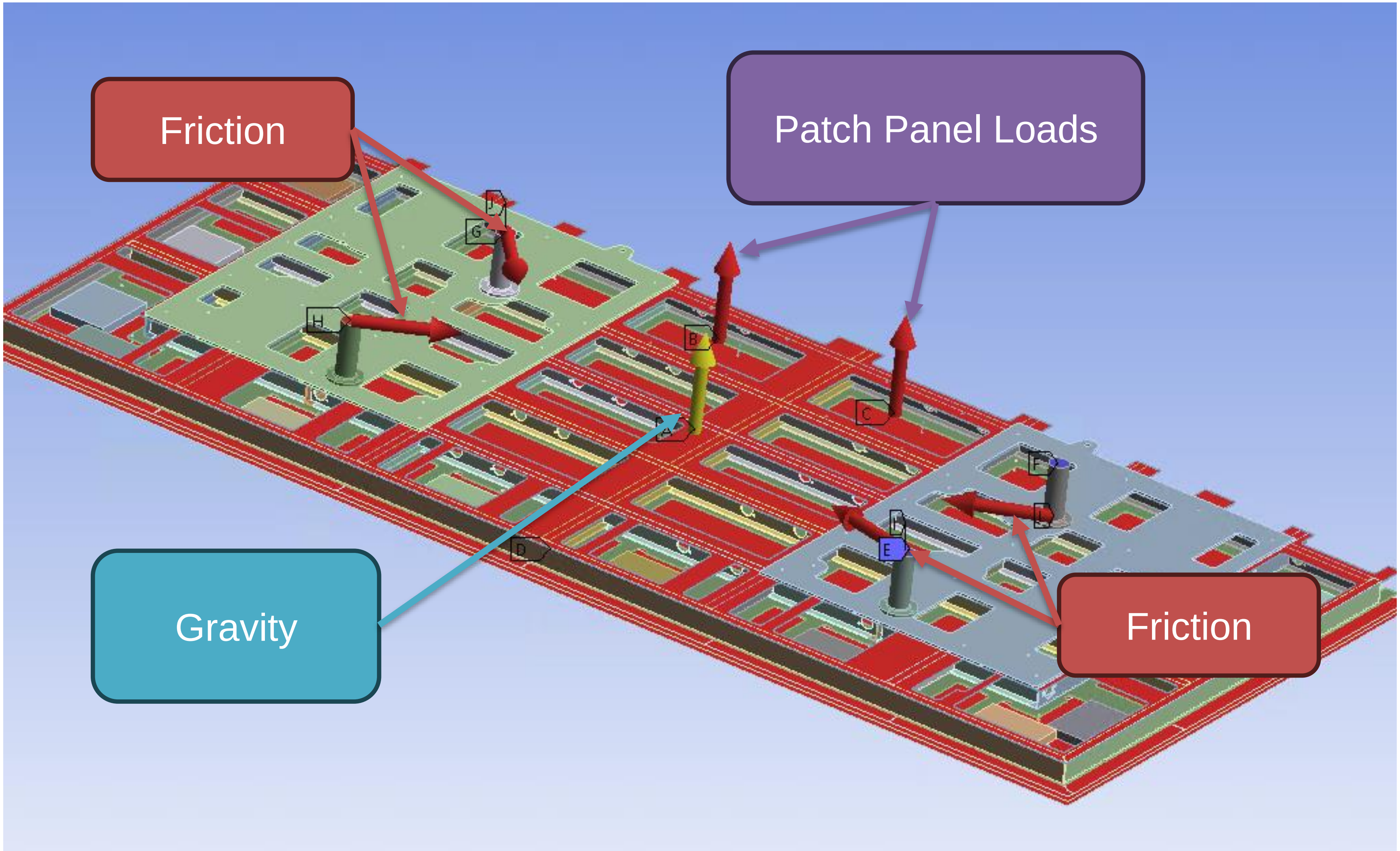
Update overview

- New bottom support design: adjustable sliding on membrane floor supports for CRU
- Stress in the CRU: effect of differing adapter plate material and thickness

Overview of Stress Model

- Real component geometry is modelled.
- Supports are all linear; one foot is fixed, and the others are treated as frictional.
  - We’ve established that this is an appropriate simplification in previous models and meetings.
- Forces from sliding can be applied to the feet to simulate a maximum state of stress that occurs during contraction.
- This is when the CRU is cold, but before it is submerged.
- The stresses when submerged will be lower, due to decreased mechanical loads.
- We use the worst-case combination of CTEs for the CRU and adapter plates.

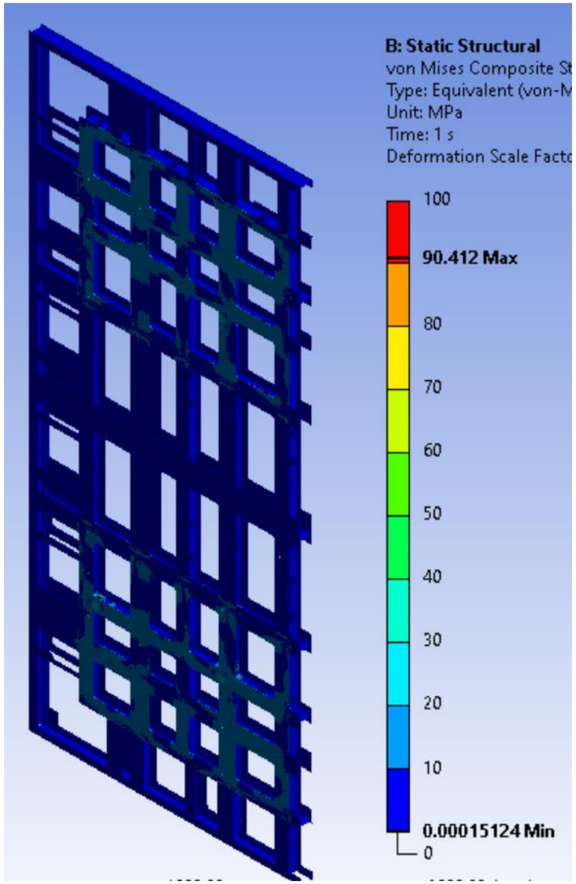
Image of Stress Model Loads



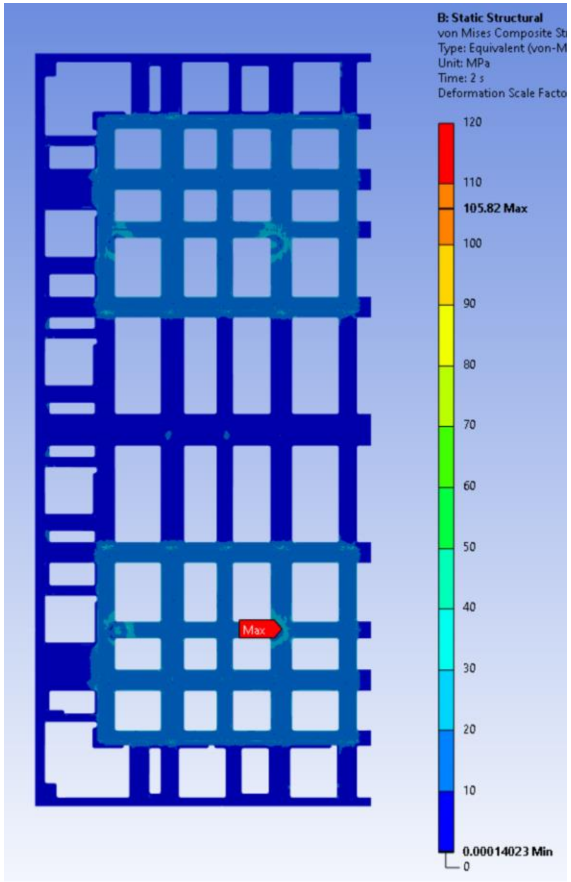
Parameters for Following Results

1. Both adapter plates have a uniform thickness of 6.35mm.
2. One set of results assigns the material as G10 we will use this as the baseline.
    1. The secant coefficient of thermal expansion is set to be the minimum value for G10.
    2. The secant coefficient of thermal expansion is set to be the maximum value for the structure.
    3. This combination is the most conservative estimate of the thermal strains.
3. The other set of results assigns the material as AISI 304 stainless steel.
    1. The secant coefficient of thermal expansion is set to the maximum for AISI 304.
    2. The secant coefficient of thermal expansion is set to the minimum for the structure.

Von Mises Stress - Structure

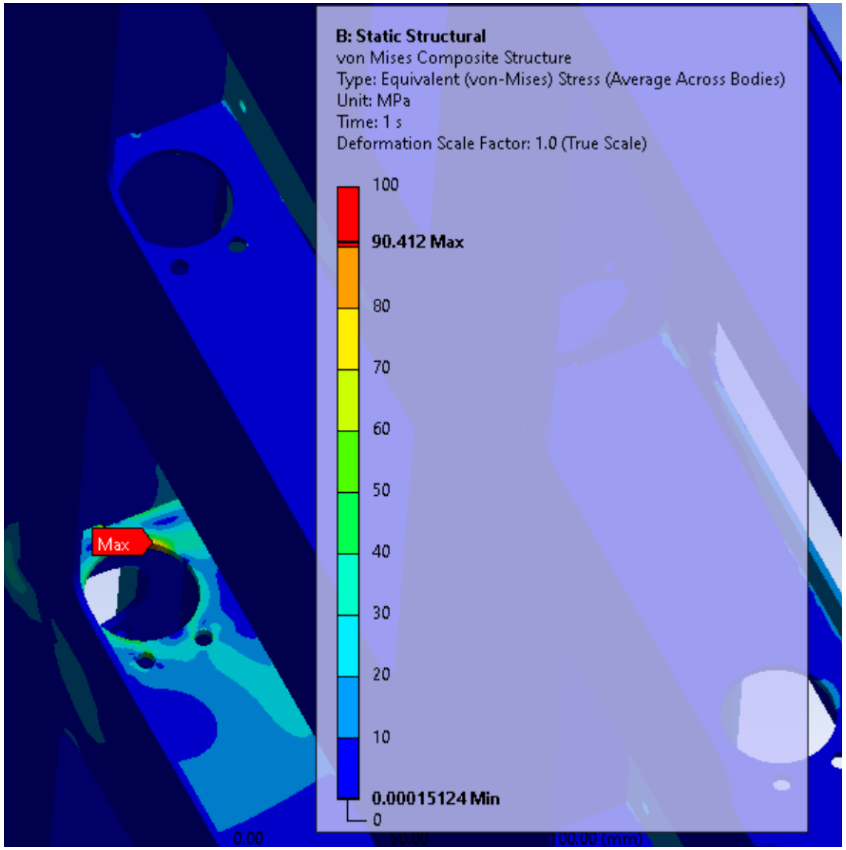


G10 Adapter Plate

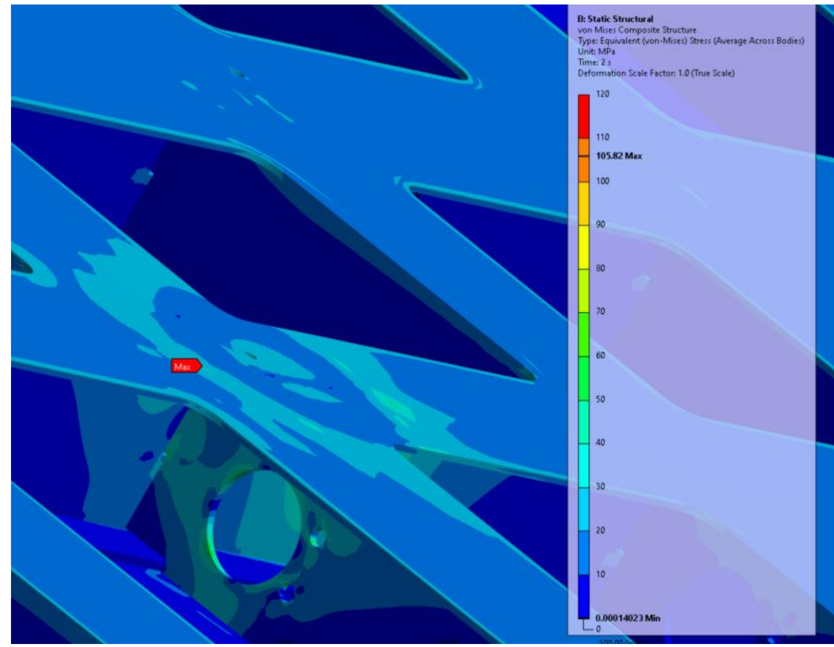


AISI 304 Adapter Plate

Von Mises Stress - Structure

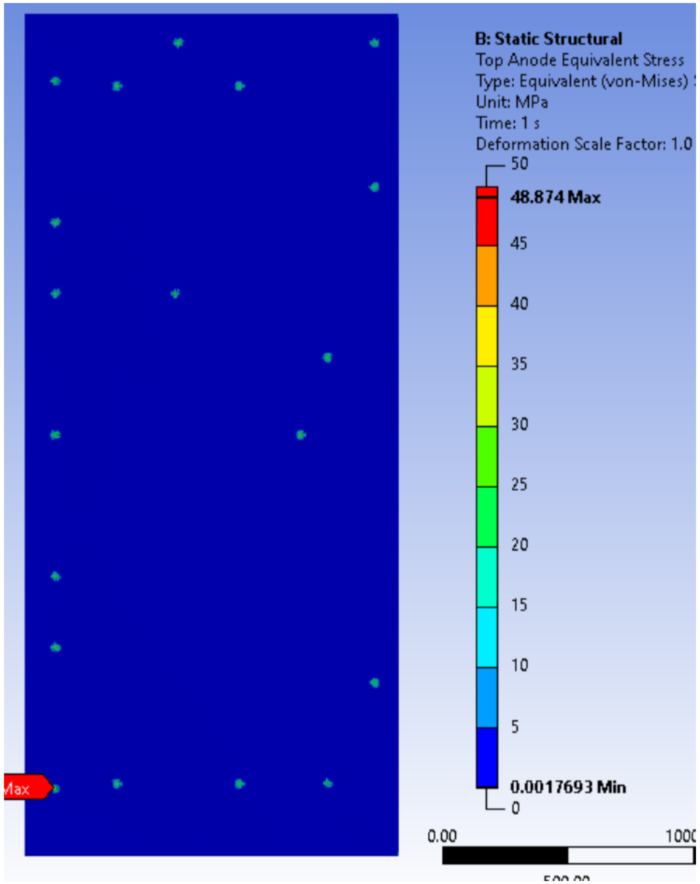


G10 Adapter Plate

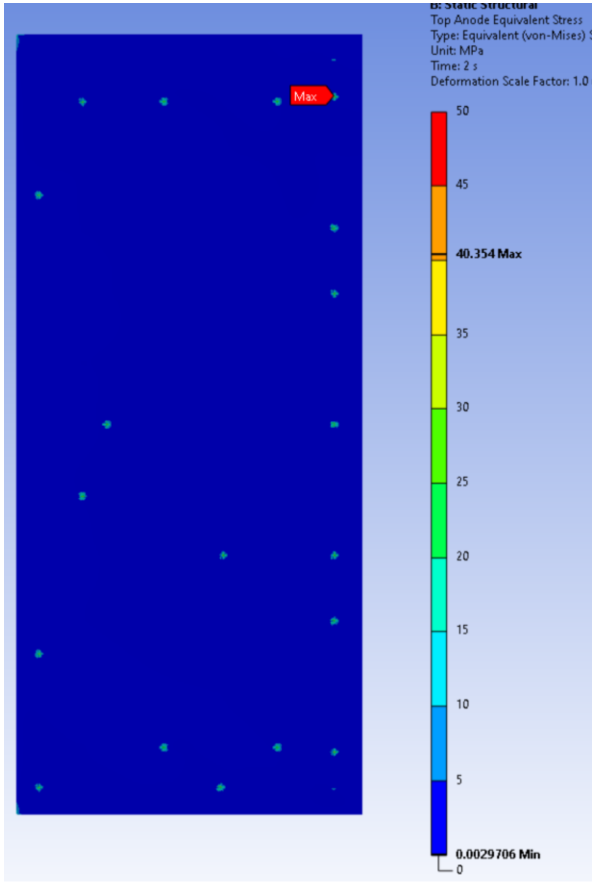


AISI 304 Adapter Plate

Von Mises Stress – Top Anode

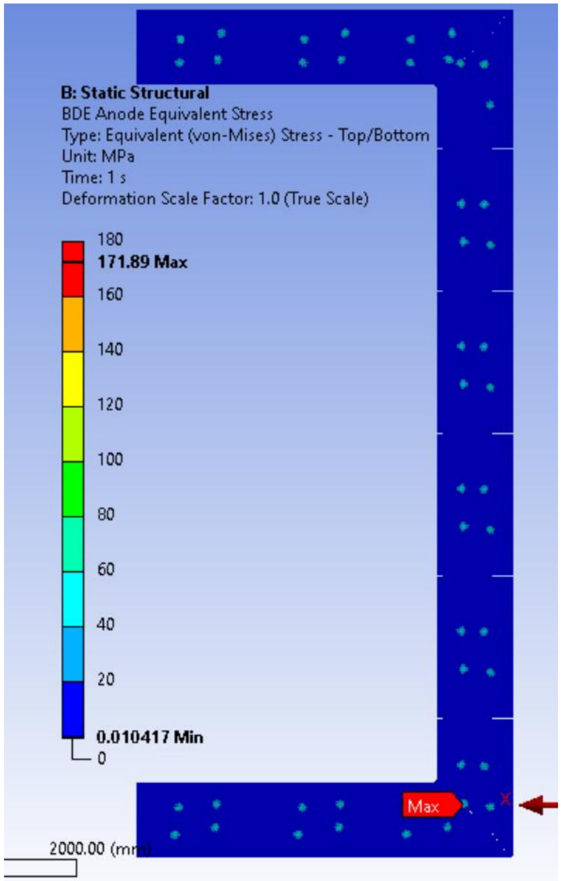


G10 Adapter Plate

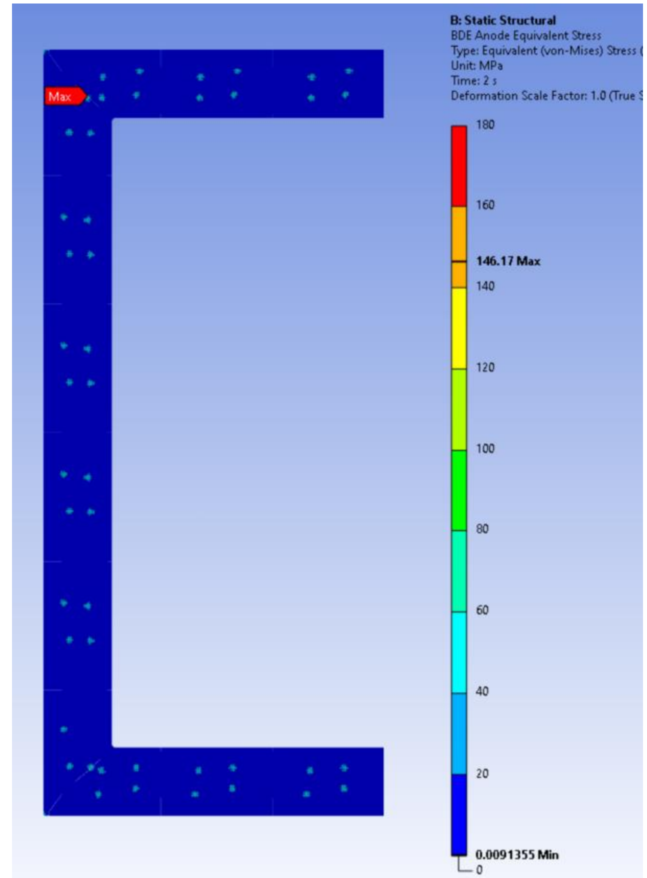


AISI 304 Adapter Plate

Von Mises Stress – BDE

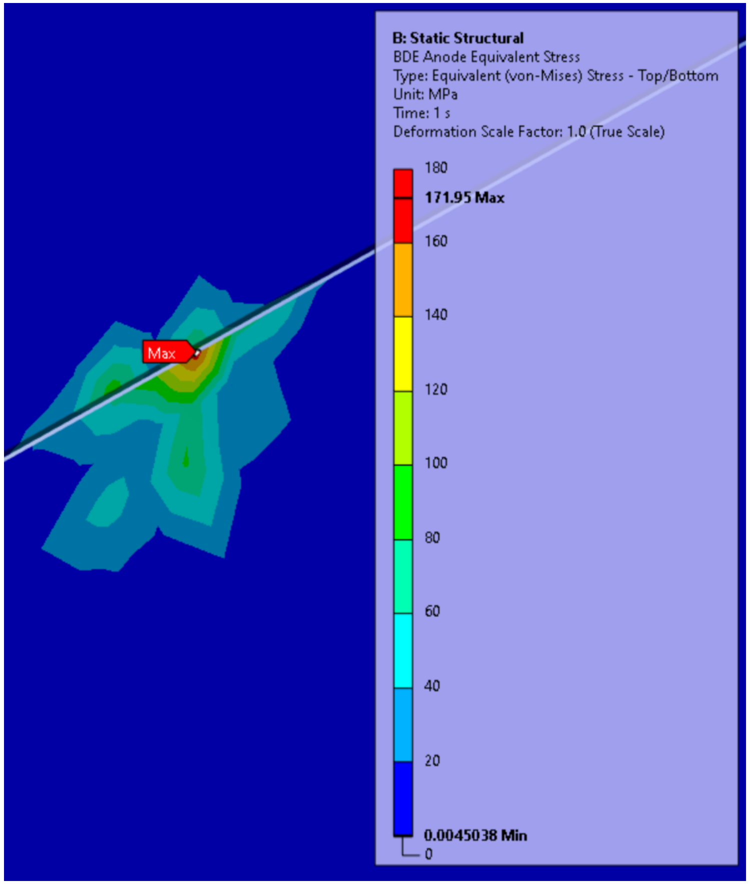


G10 Adapter Plate

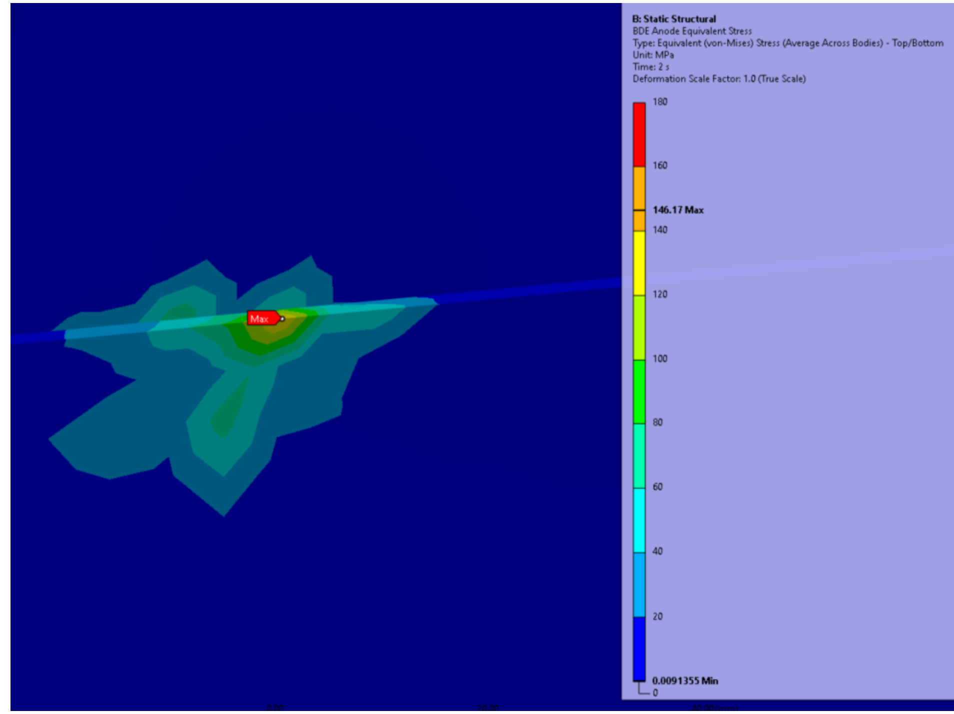


AISI 304 Adapter Plate

Von Mises Stress – BDE

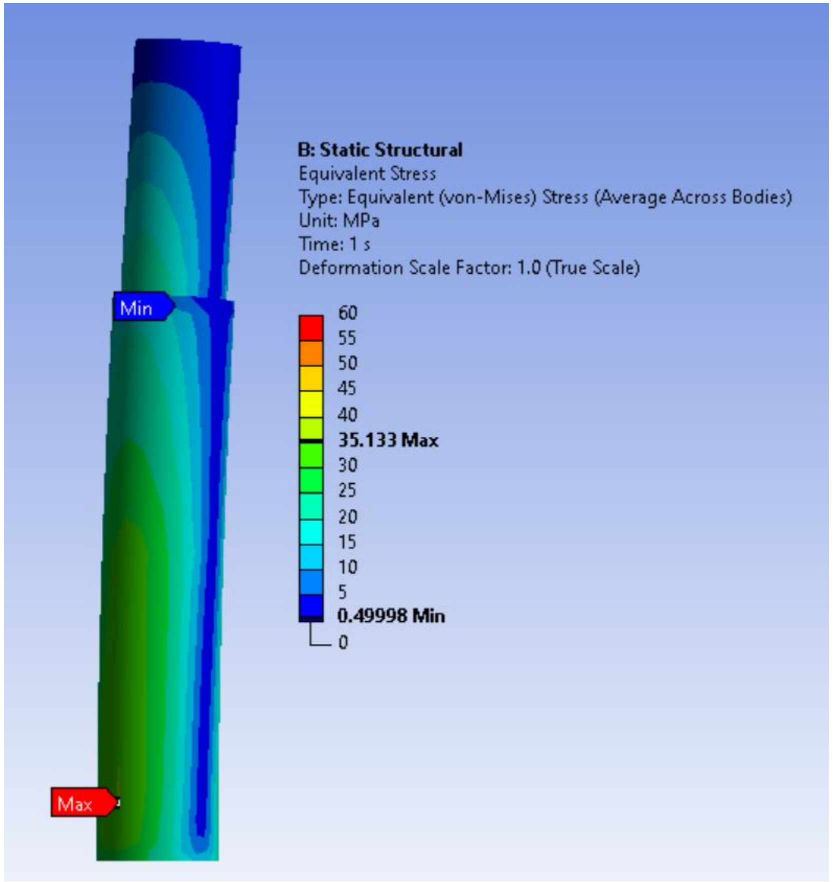


G10 Adapter Plate

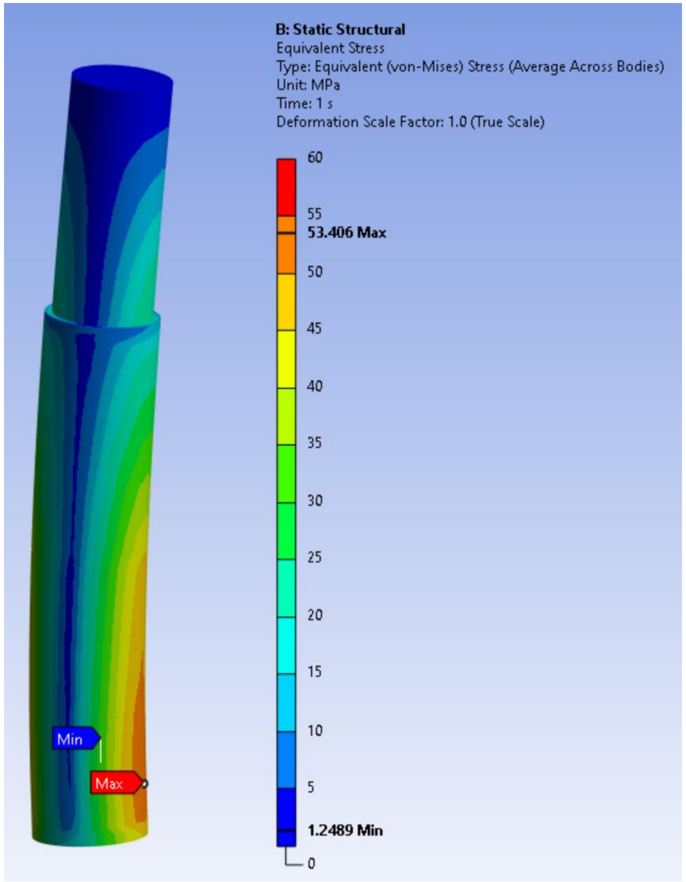


AISI 304 Adapter Plate

Von Mises Stress – Anode Spacer

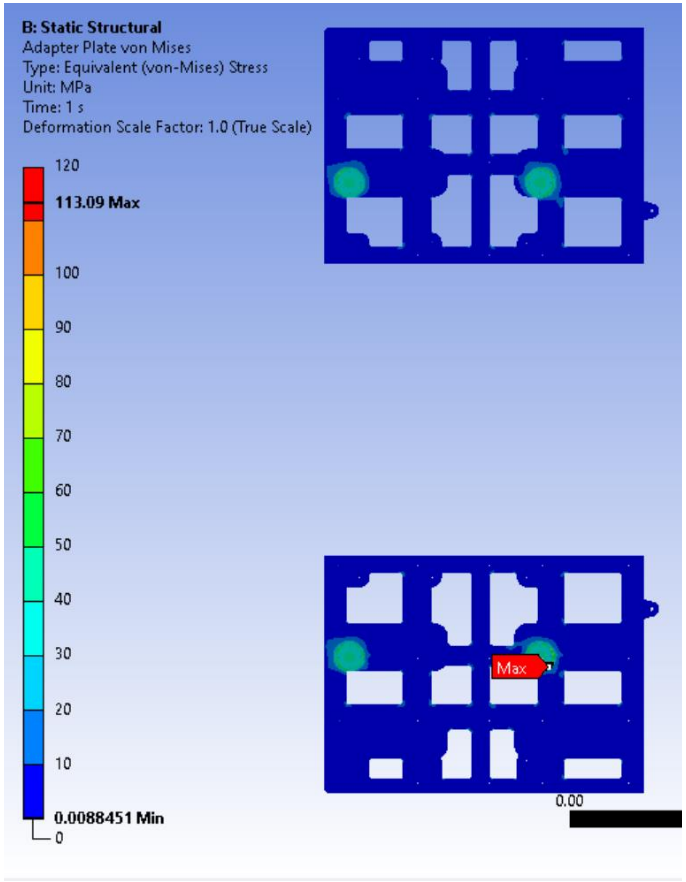


G10 Adapter Plate

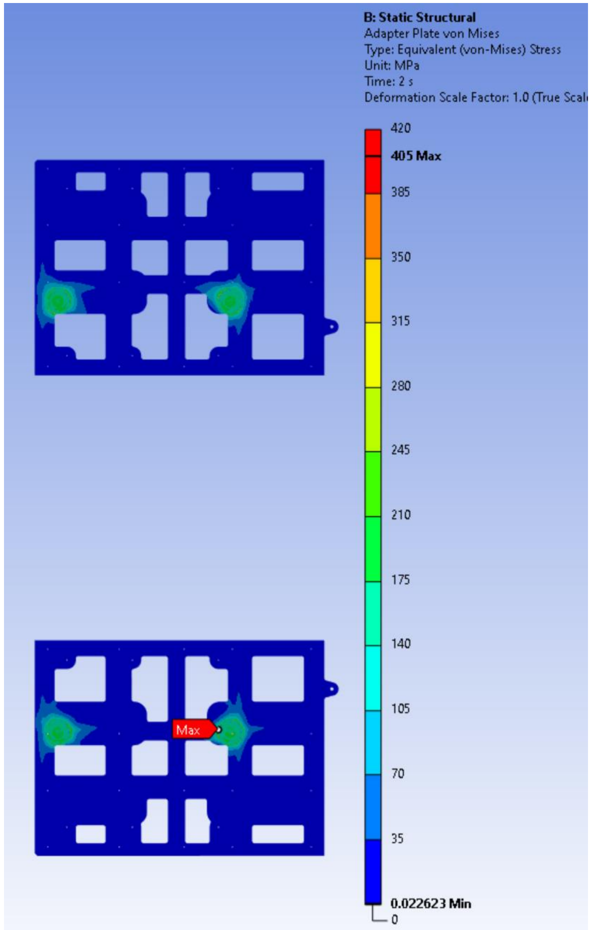


AISI 304 Adapter Plate

Von Mises Stress - Adapter Plate

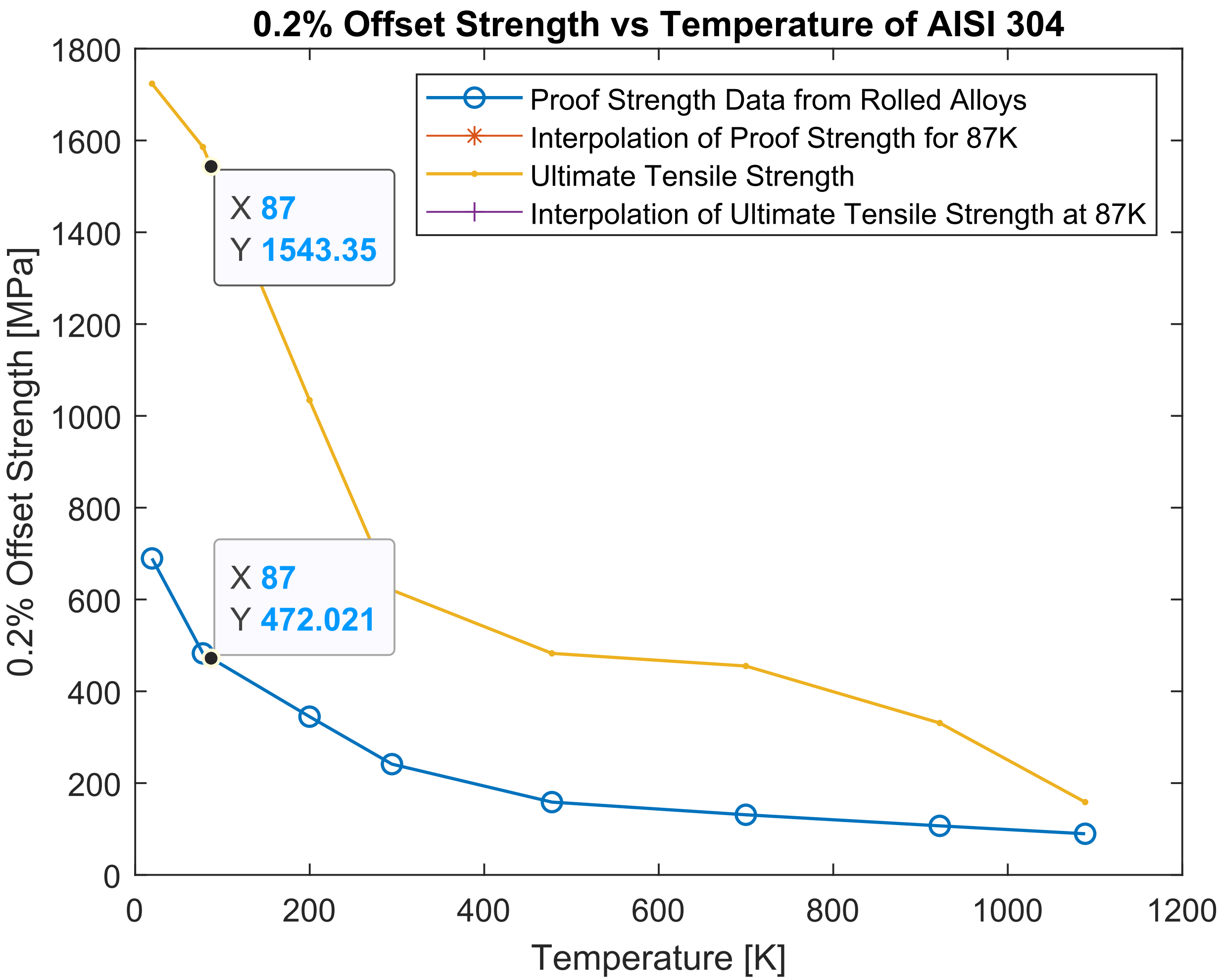


G10 Adapter Plate



AISI 304 Adapter Plate

AISI 304 @ 87K



- The tensile yield strength increases as temperature decreases to 472 MPa.
- The tensile ultimate strength also increases, so the material doesn't get too brittle.
- With these values, the final state of stress is now below the yield stress.

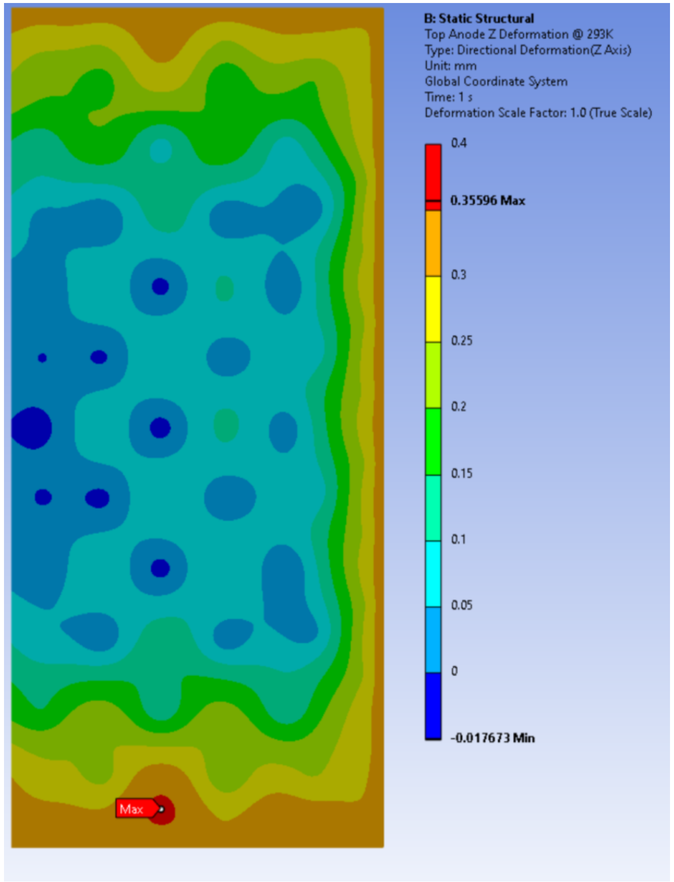
Summary of Results

Component	Material Yield Stress [MPa] @ 87K	Maximum von Mises Stress [MPa] (G10 Adapter Plate)	Maximum von Mises Stress [MPa] (AISI 304 Adapter Plate)	Resulting Safety Factor [-] (G10 Adapter Plate)	Resulting Safety Factor [-] (AISI 304 Adapter Plate)
Anodes	440.1	48.874	40.368	9	10.90
BDE Board	440.1	171.84	146.24	2.56	3.01
Composite Structure	440.1	90.41	106.17	4.87	4.15
Anode Spacers	90.9	33.695	54.137	2.70	1.68
Adapter Plate (G10)	375	113.09	-	3.32	-
Adapter Plate (304)	472	-	405.95	-	1.16

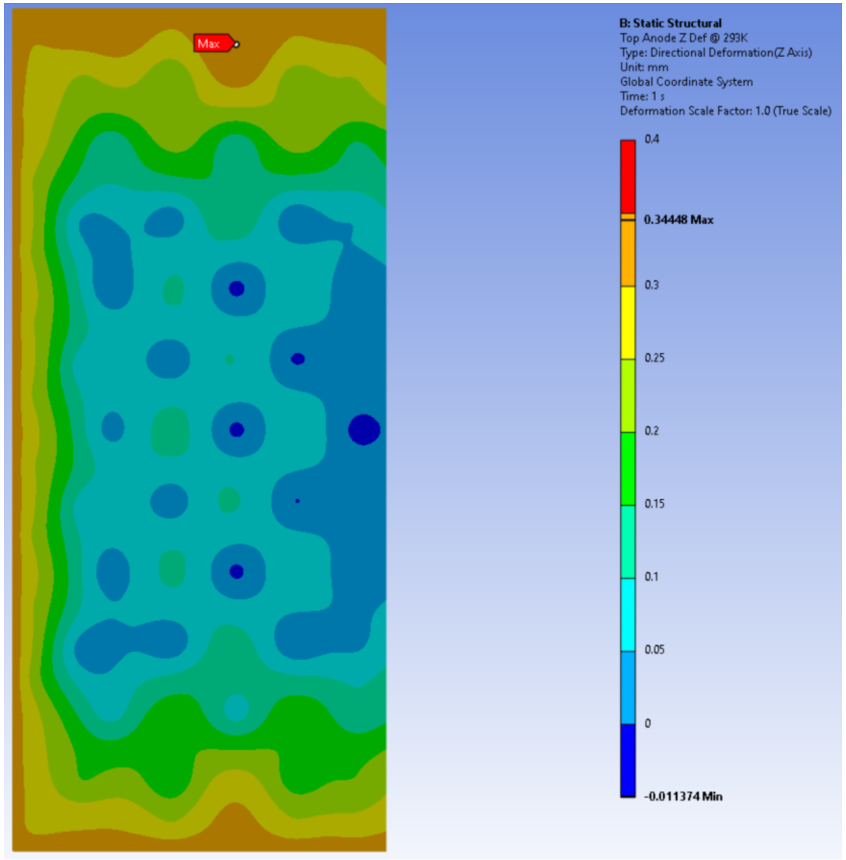
Thinner Stainless Steel Adapter Plate Motivation

- A thinner adapter plate saves material cost and reduces mass.
  - 4.76mm vs 6.35mm
- Machining costs could also be slightly lower with a thinner adapter plate.

Top Anode Warm State Deflection

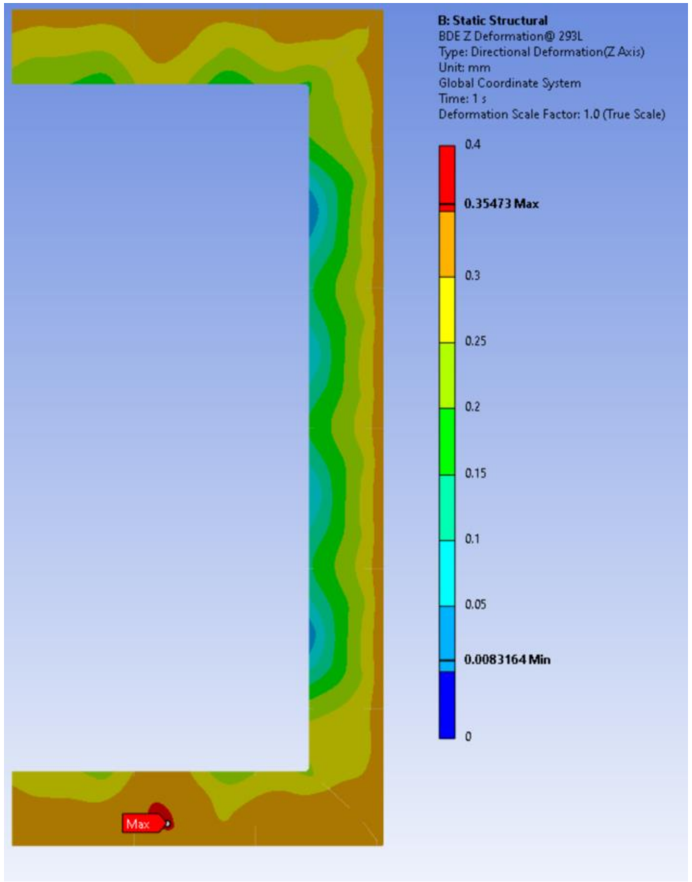


6.35mm AISI 304

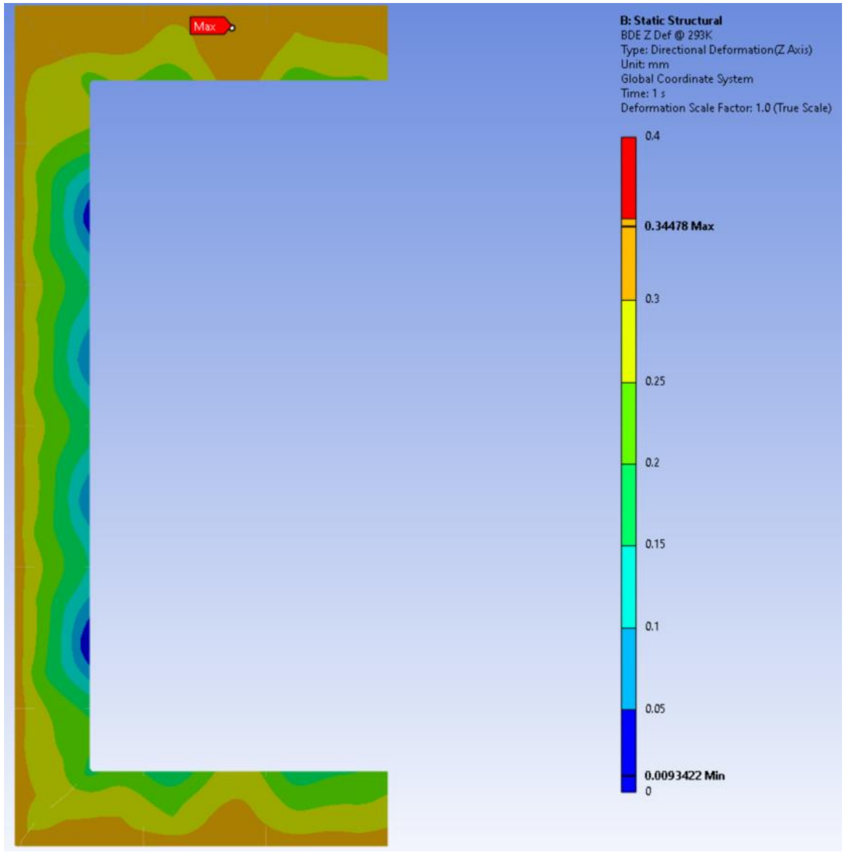


4.76mm AISI 304

BDE Warm State Deflection

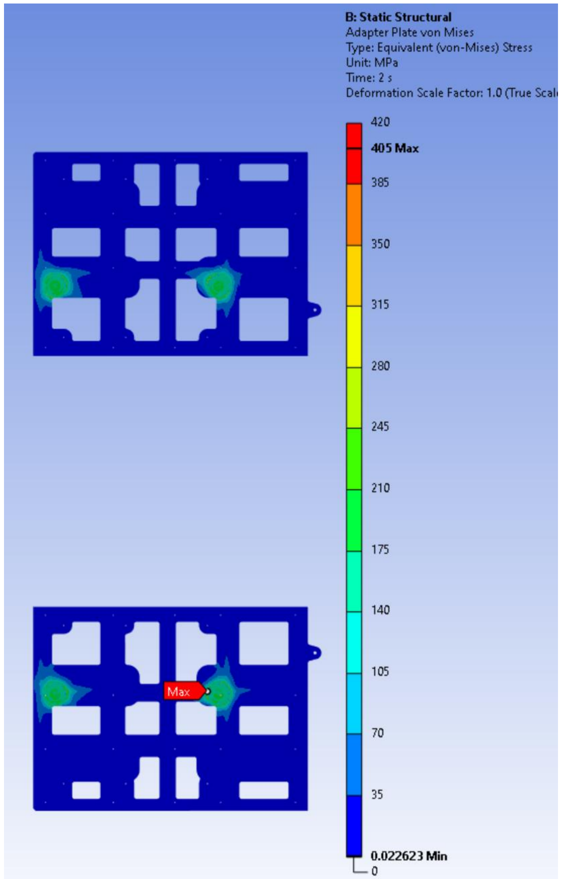


6.35mm AISI 304

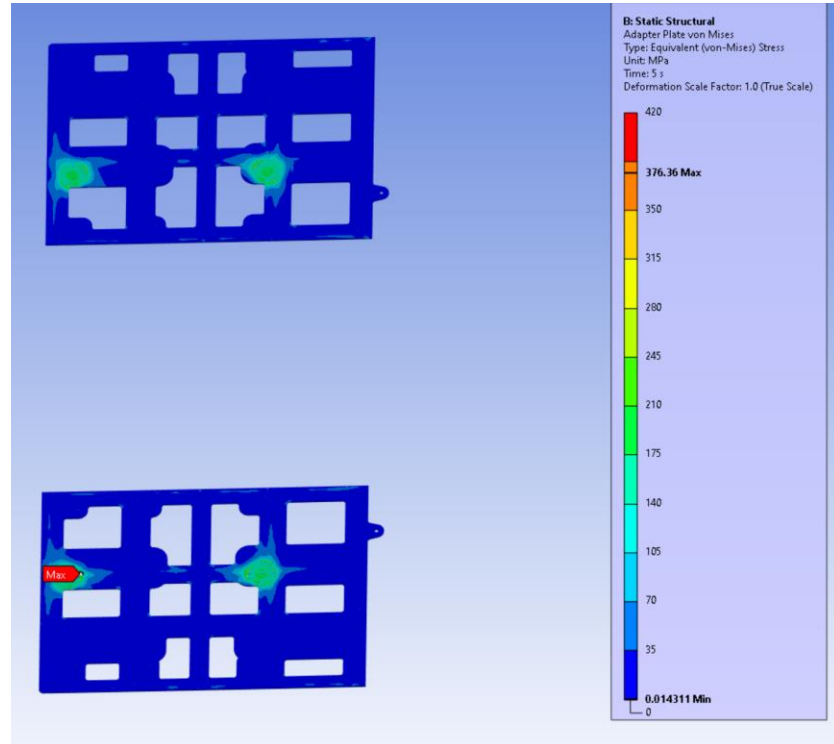


4.76mm AISI 304

Adapter Plate von Mises Stress

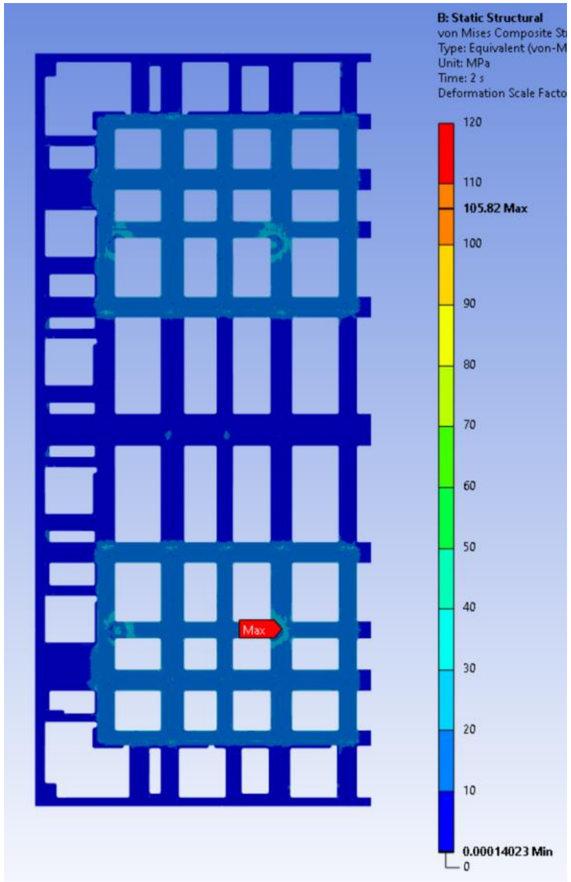


6.35mm AISI 304

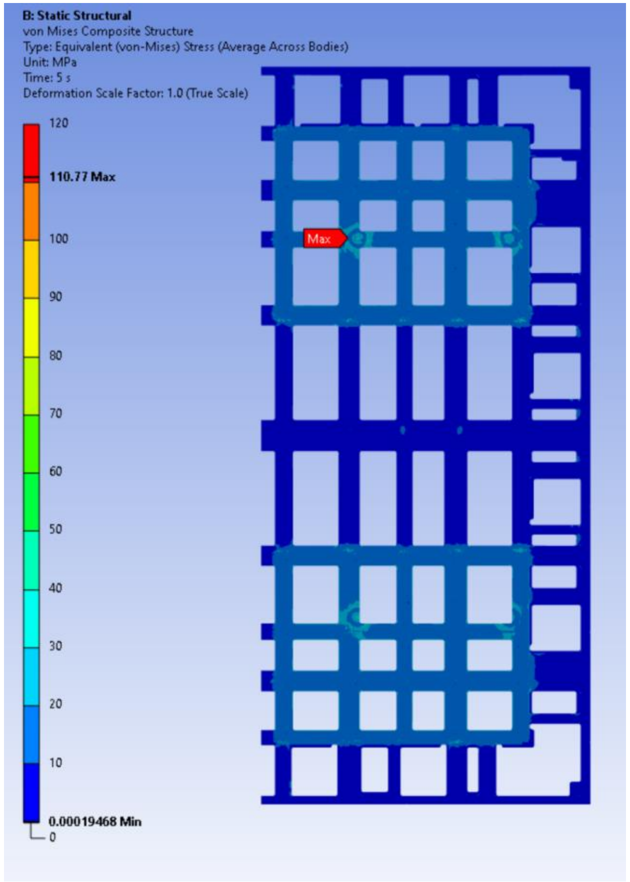


4.76mm AISI 304

Structure von Mises Stress

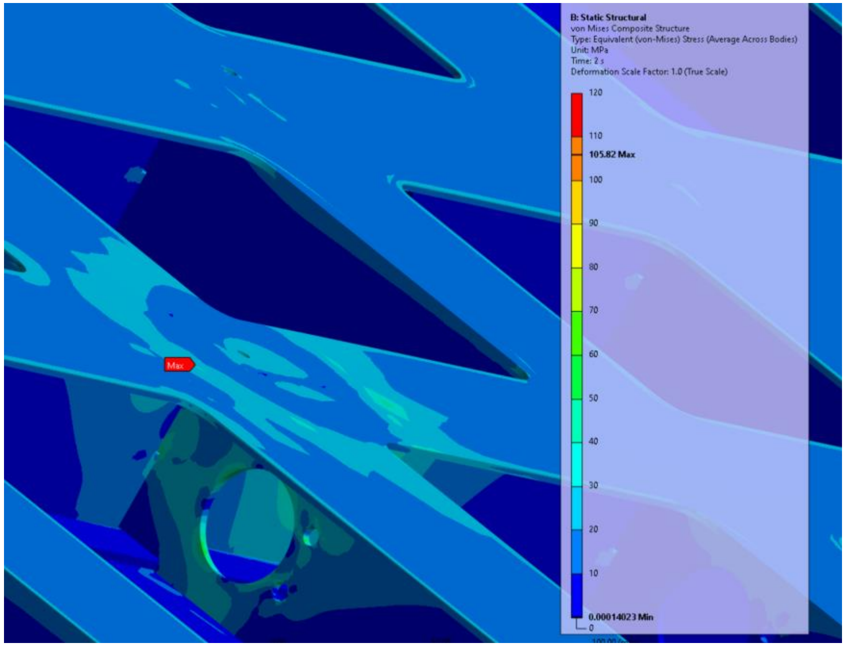


6.35mm AISI 304

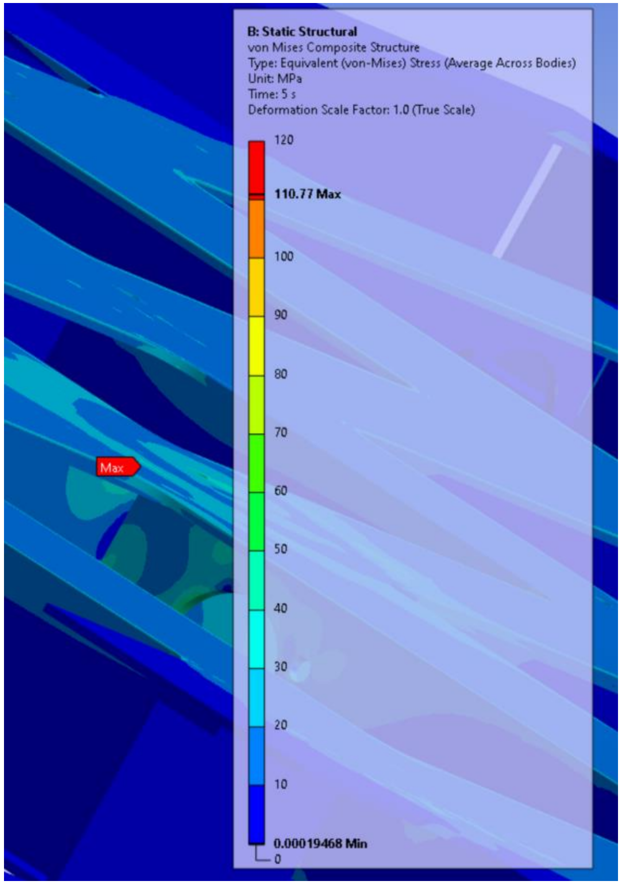


4.76mm AISI 304

Structure von Mises Stress

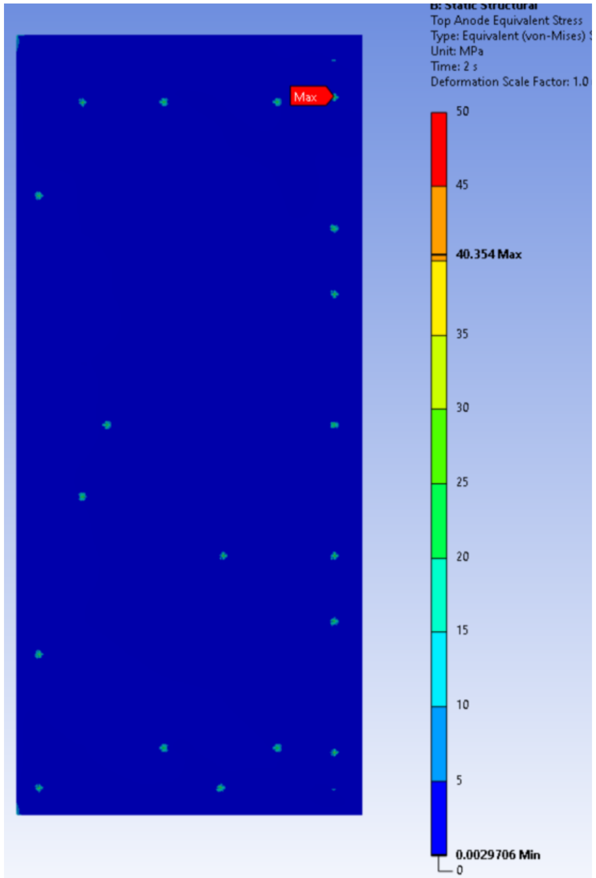


6.35mm AISI 304

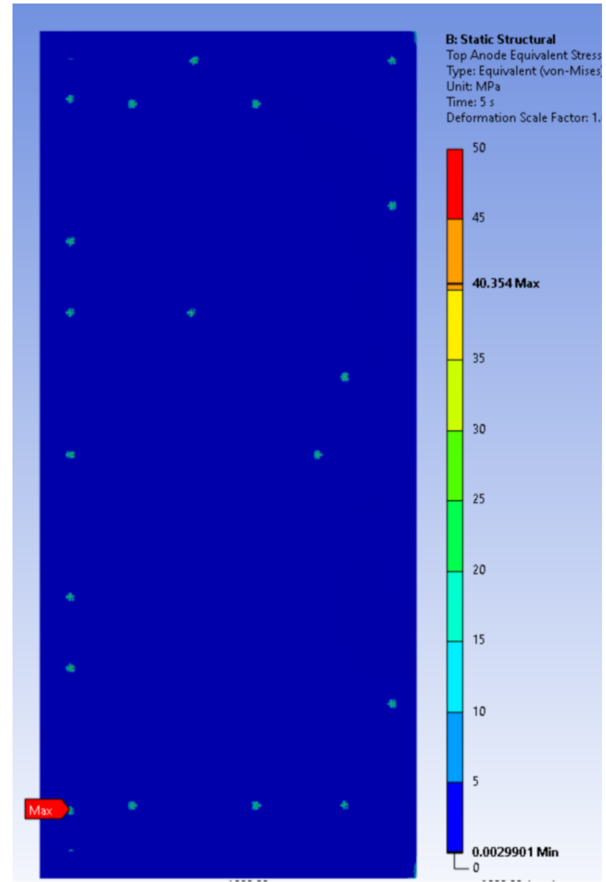


4.76mm AISI 304

Structure von Mises Stress

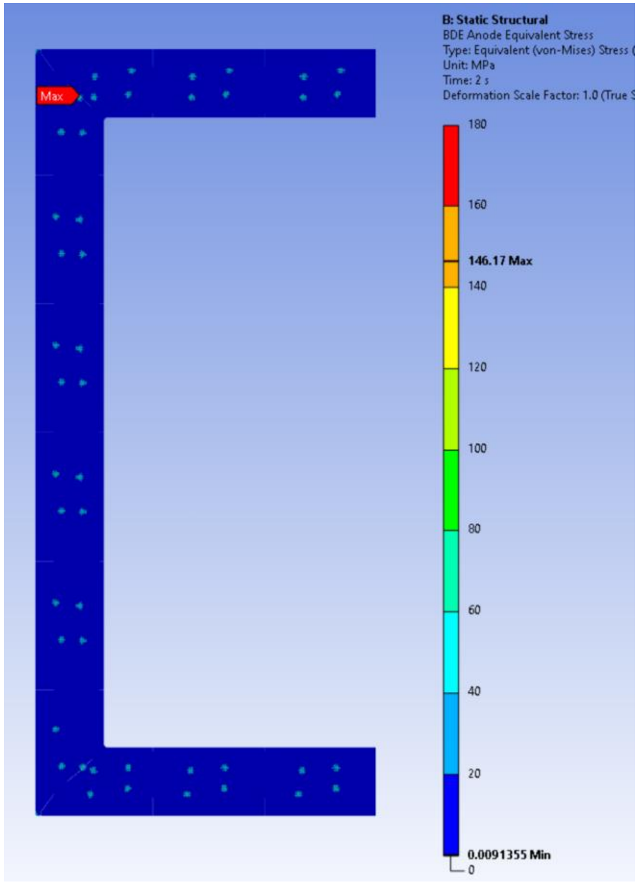


6.35mm AISI 304

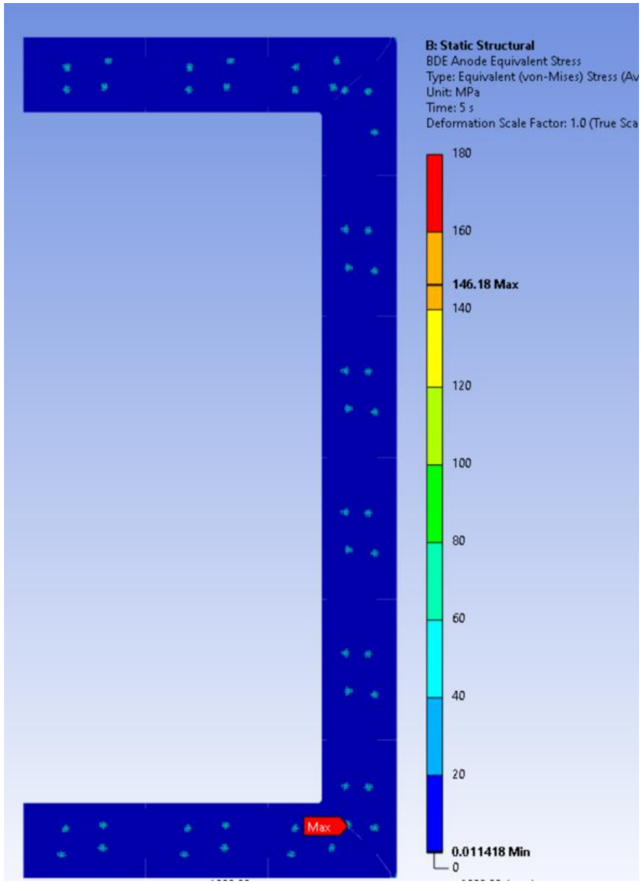


4.76mm AISI 304

Structure von Mises Stress

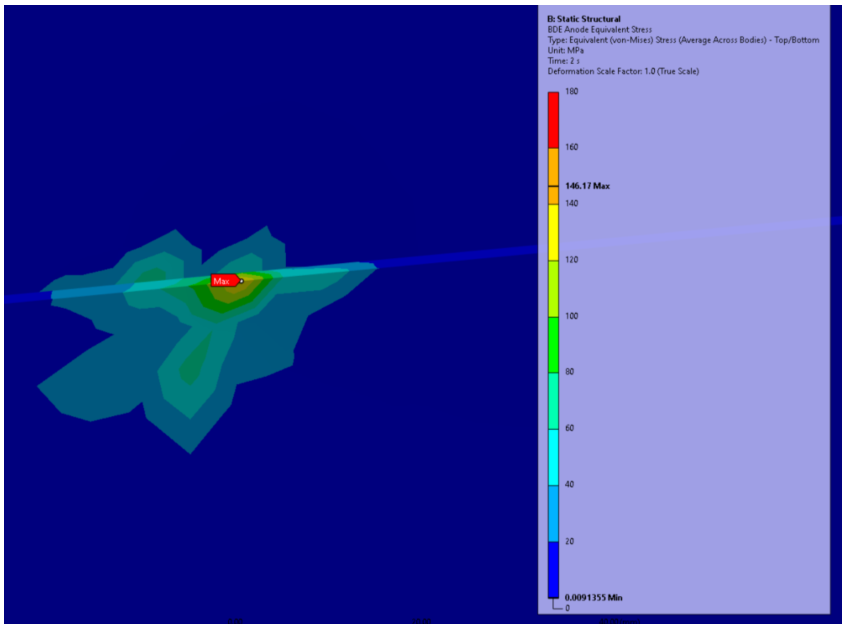


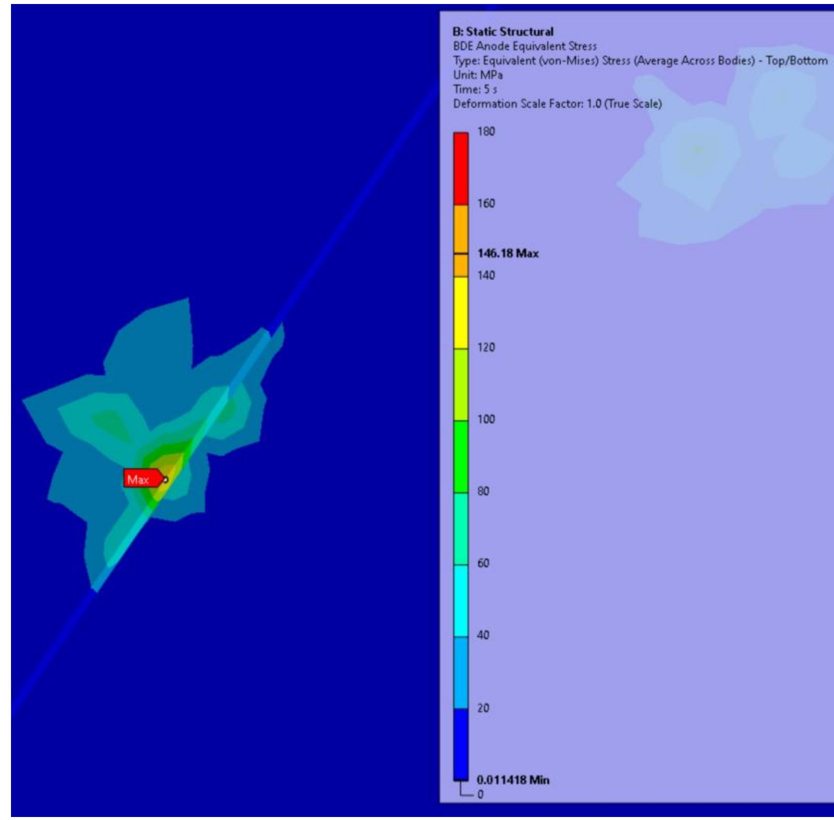
6.35mm AISI 304



4.76mm AISI 304

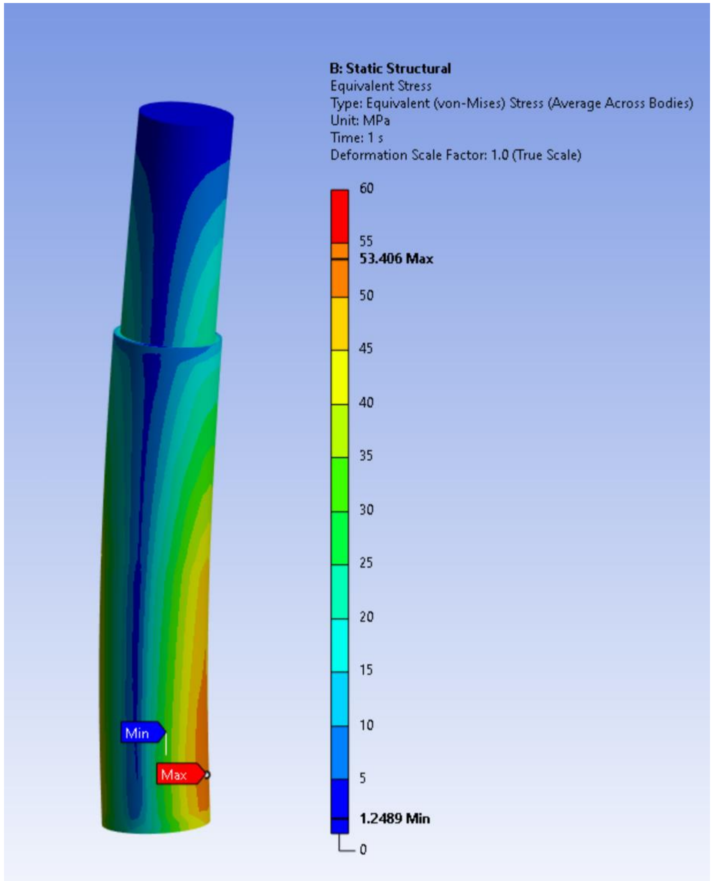
Structure von Mises Stress



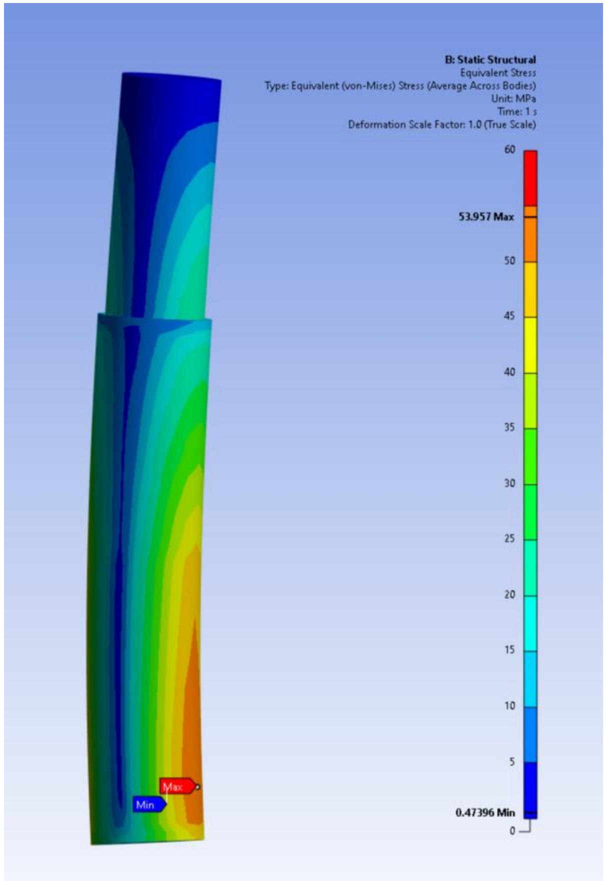


6.35mm AISI 304 | 4.76mm AISI 304

Structure von Mises Stress



6.35mm AISI 304



4.76mm AISI 304

Conclusions

- The adapter plate material has a measurable impact on the stiffness of the assembly.
- G10 provides less stiffness which allows for more vertical deflection in the PCB planes but is more forgiving to the PEEK spacers and slightly more forgiving for the composite structure.
- Stainless steel provides more stiffness which reduces the vertical deflection in the PCB planes but is harsher on the PEEK spacers and slightly harsher for the composite structure.
- The thickness of the stainless-steel adapter plate is not a significant variable in any of the results.
- To make a judgement based on cooldown we should consider what stresses the compliance office is willing to deem acceptable during cooldown.

Upcoming Work

- Begin analysis of the submerged condition.
- Begin analysis of the flipping tool case.
- Begin analysis of the tine lifting system case.
- Apply randomized coefficients of friction to the contraction position model and determine the variance in position.
- Introduce the most extreme foot position (those with the largest asymmetry, the narrowest base, and widest base) to the thermal contraction position model and stress model.