Bottom CRP Installation: Structural Modeling

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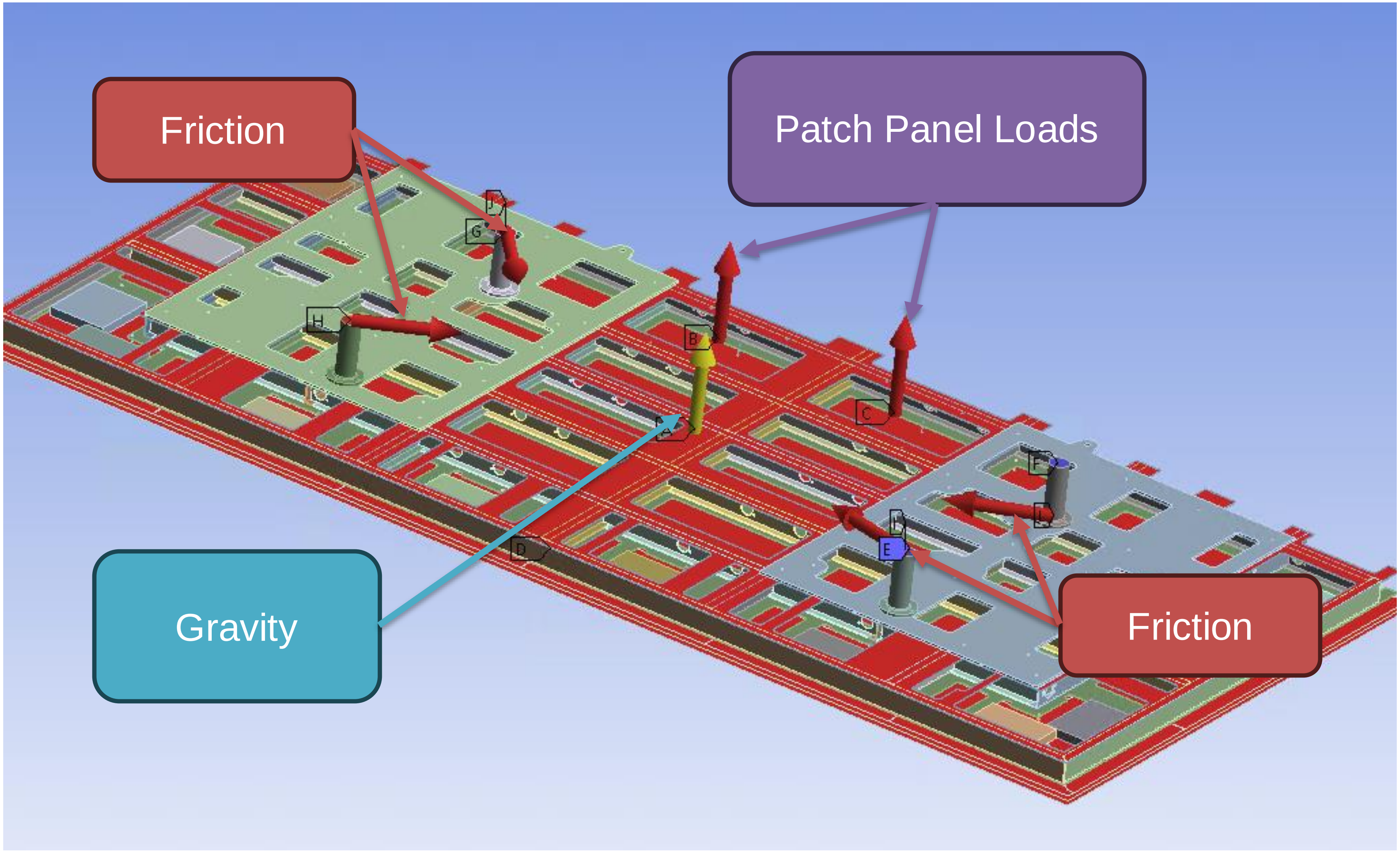
Overview of Stress Model

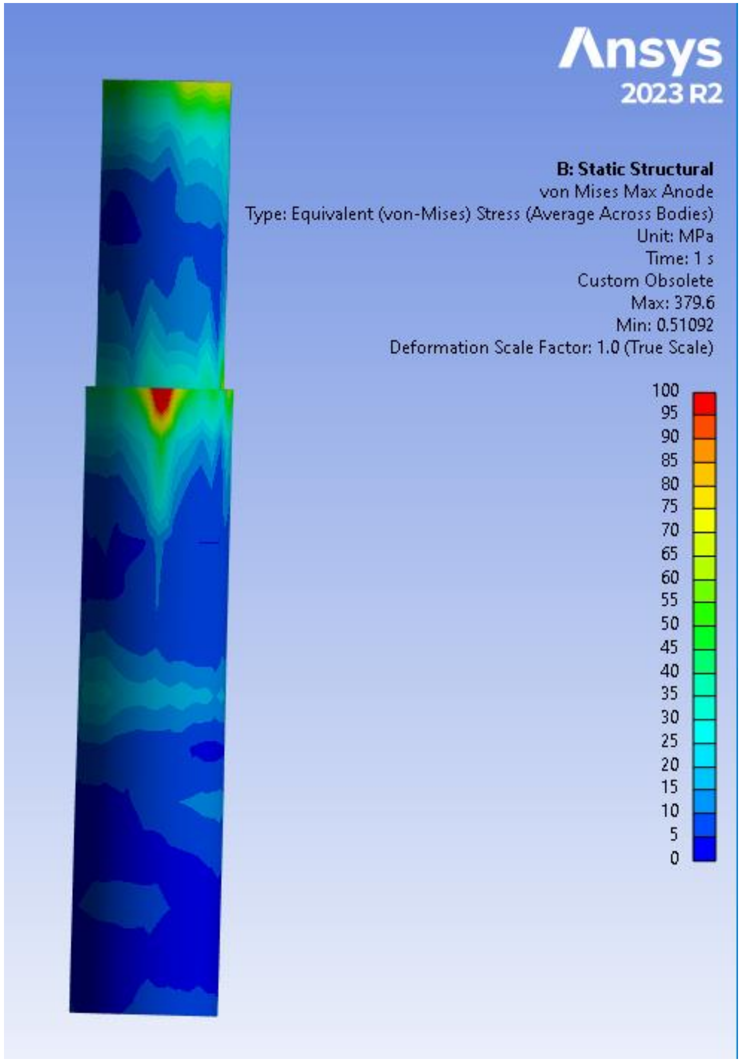
- Real component geometry is modelled.
- Supports are all linear; one foot is fixed, and the others are treated as frictional.
  - We've established that this is an appropriate simplification in previous models and meetings.
- Forces from sliding can be applied to the feet to simulate a maximum state of stress that occurs during contraction.
- The adapter plate is made from G10.
- 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



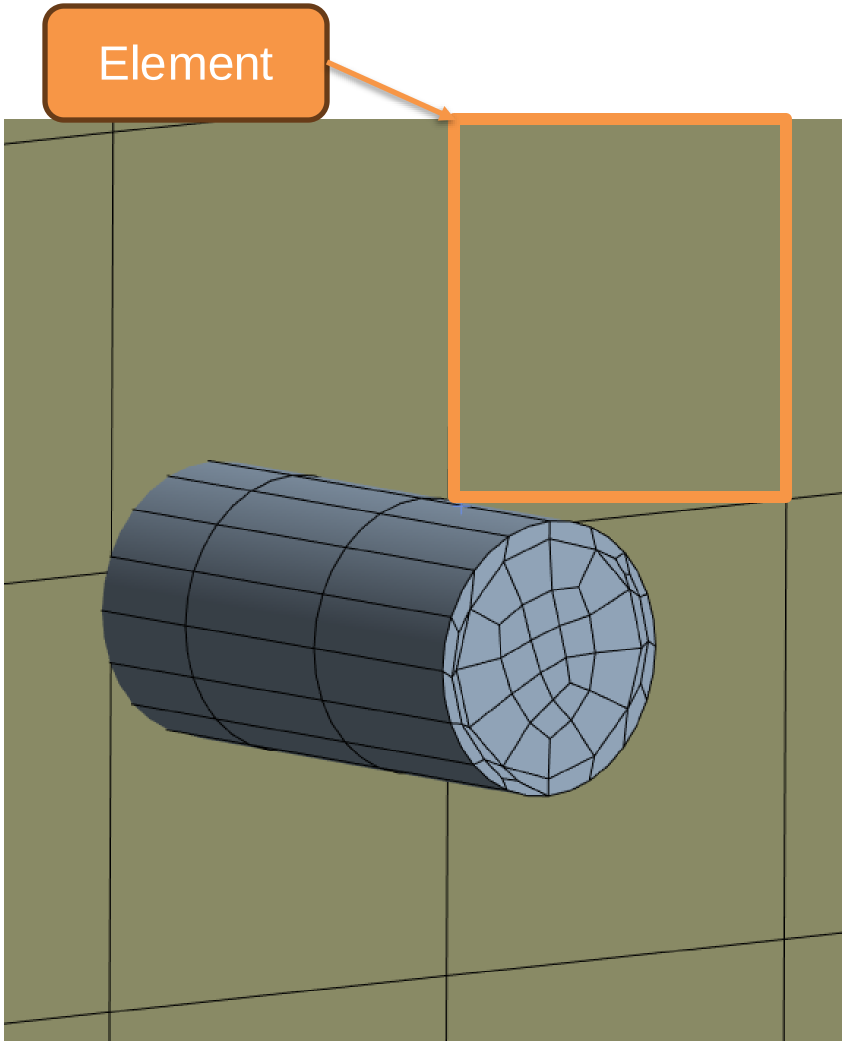
Anode Spacers

- Our linear elastic model overestimates the stress within the spacers.
- This is due to how the contact between the PCBs and the anode is being formulated.
- Additionally, a linear elastic model is not a great choice for polymers.
- We can sub-model the PEEK spacers with plasticity.
- We extract the reaction forces on each of the faces which interface with the PCBs.



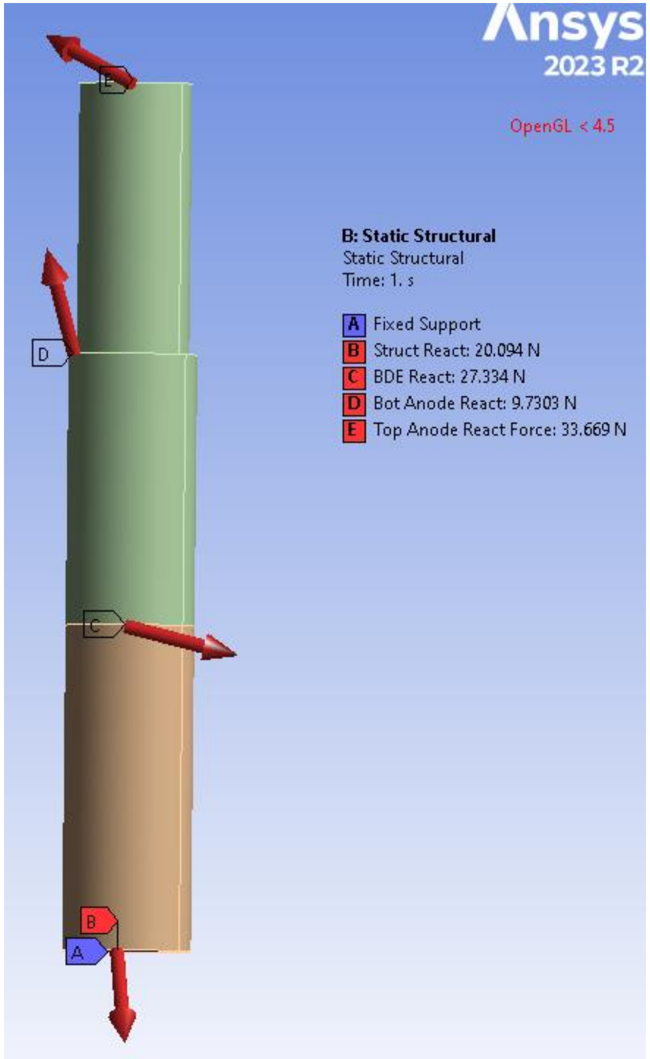
Contact in the Thermal Contraction Model

- Since the mesh of the PCBs is so coarse, only a handful of nodes will ever participate in contact.An entire spacer can is in contact with on andode plane node.
- Contacts are formulated using a no penetration condition between nodes.
- Contact force is concentrated on very small element corners; this makes the stress seem very large in the thermal contraction model
- Resulting forces on spacer are still correct. These are moved to a more detailed spacer model.



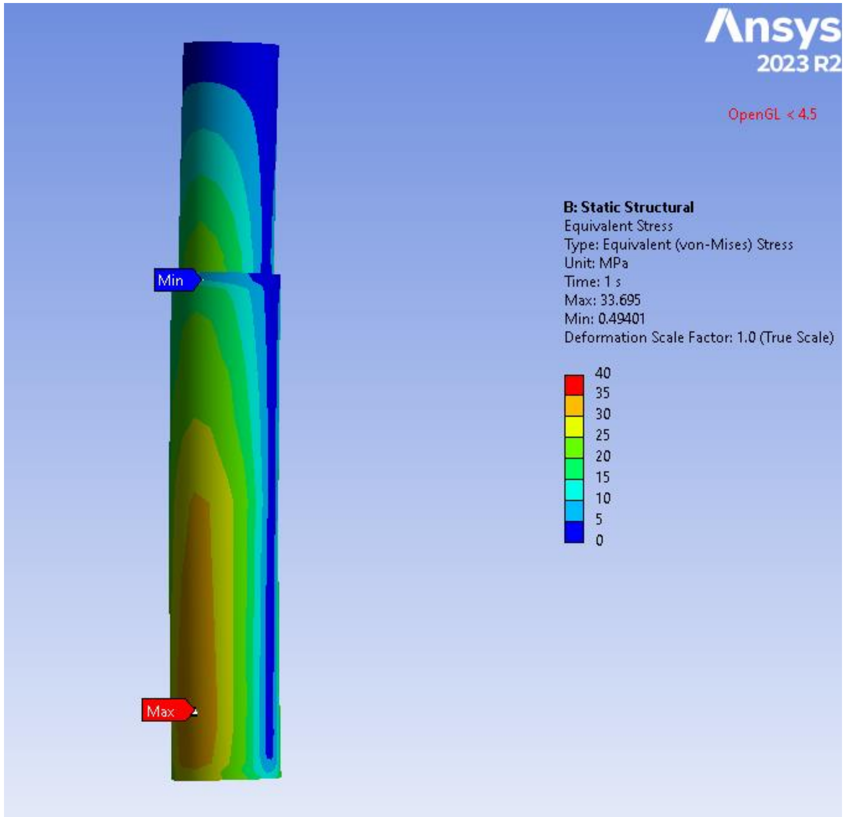
Anode Spacer Plasticity

- Using data from ANSYS Granta for unreinforced PEEK.
- We apply the loads as forces on the faces which interface with PCBs.
- D and E are interfaces with the Anode planes. Thermal contraction of these planes is the driver of these forces.
- C is the interface with the BDE, the driver here is the mass of the FEMB.
- The force at B is from the thermal contraction of the composite structure.



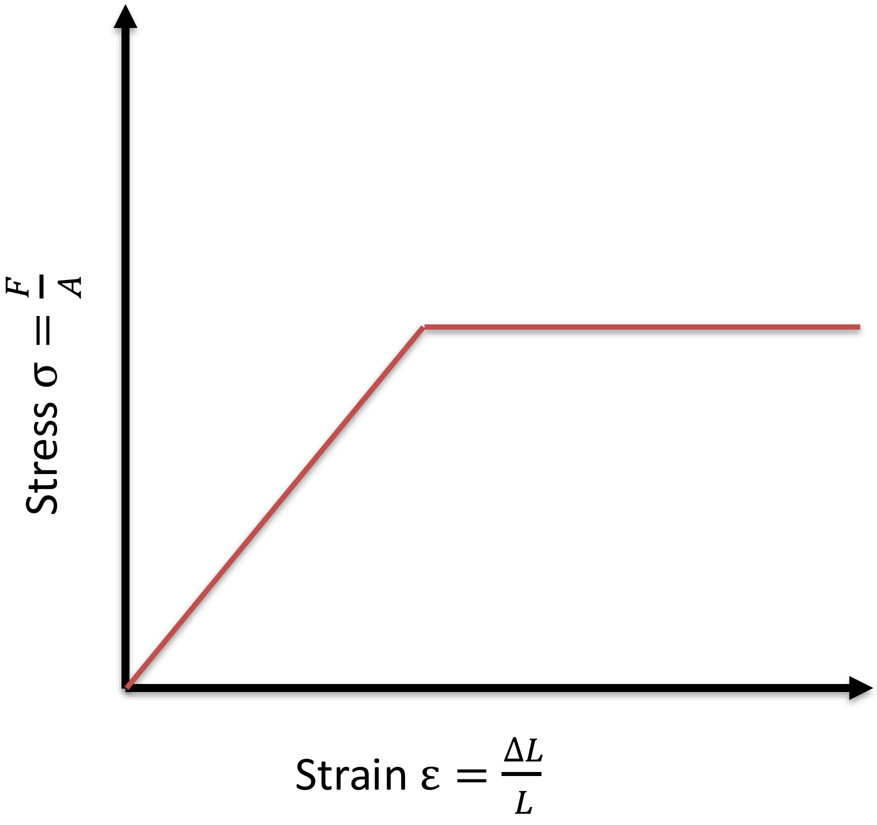
Anode Spacer Plasticity Results

- The yield strength is 90 MPa.
- The ultimate strength is 100 MPa.
- The stresses are much lower in the sub model.
  - 33.695 MPa
- I believe this is the more accurate result.



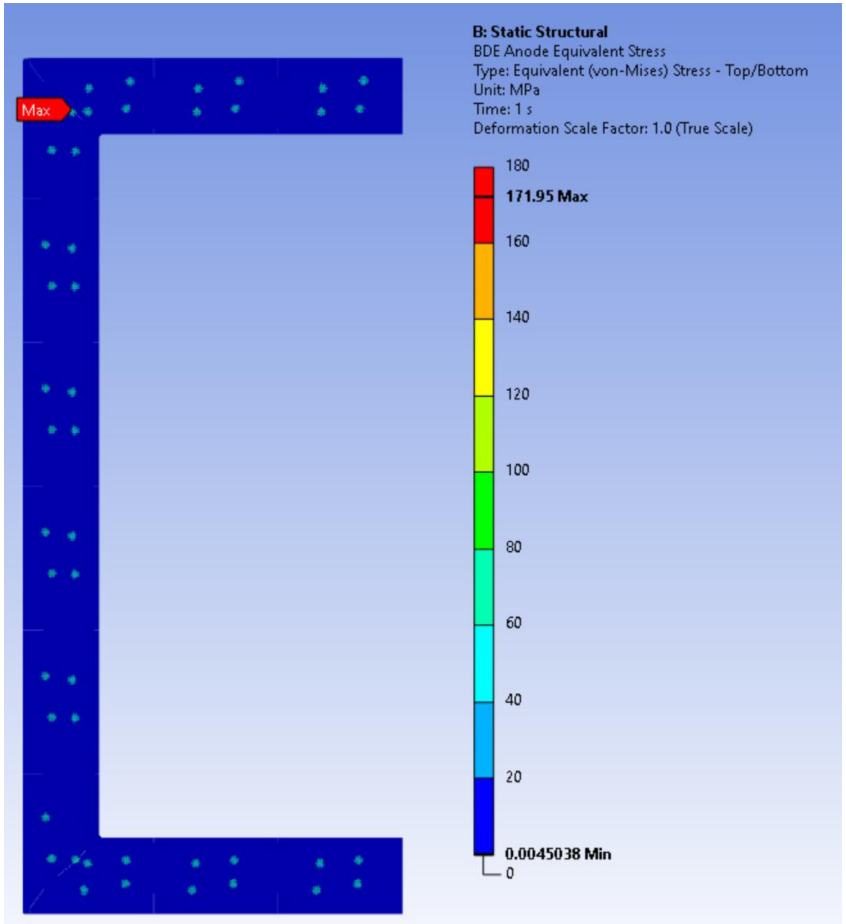
Anode Spacer Modelling Refinement

- Can we improve the larger model behavior?
- Yes; but there are tradeoffs.
- We can make the mesh on the PCBs finer, but this will add significant computation time.
- We modify the behavior of PEEK in our larger model to have a stress-strain curve as on the right. This will also add computation time; the model will need to iterate.
- I don't think either of these are worth pursuing, knowing that we can sub-model the spacers.



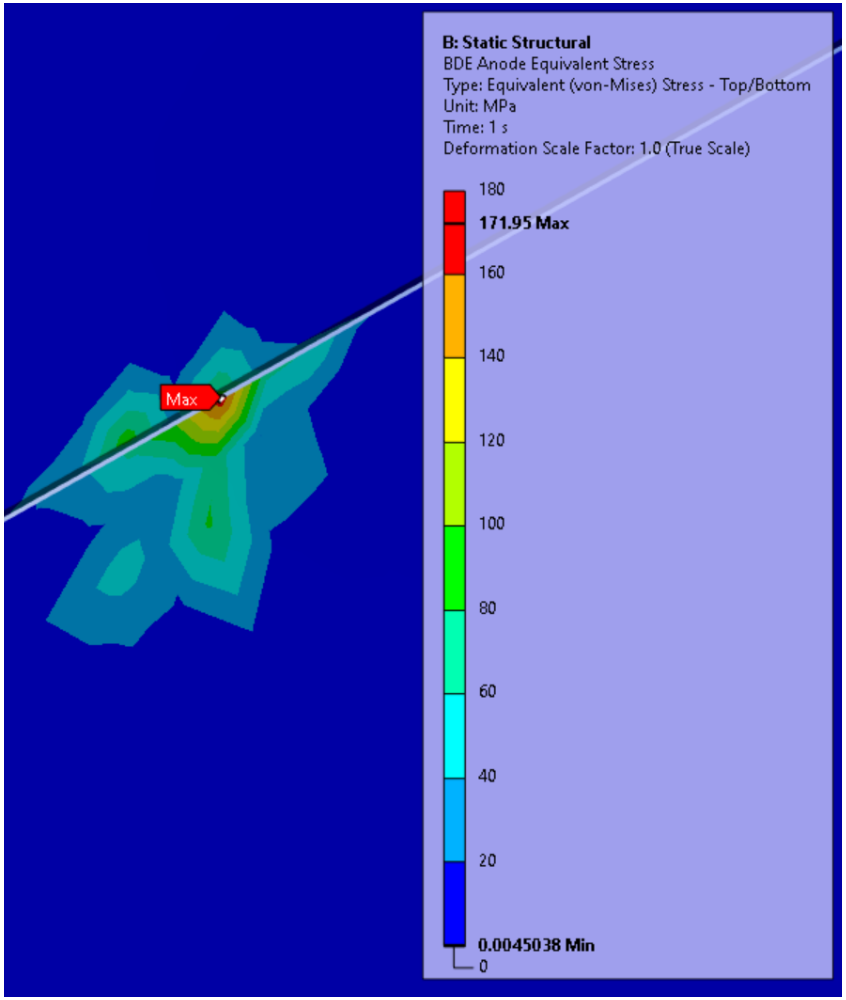
Stresses Experienced by BDE

- The overall state of stress of the BDE is very low.
  - The integral average stress across the body is 2.7 MPa.
- The maximum von Mises stress is 171.95 MPa.
- The yield point is 440.1 MPa.
- Safety factor of 2.559 using the maximum.
  - No strength factor from compliance office applied here.



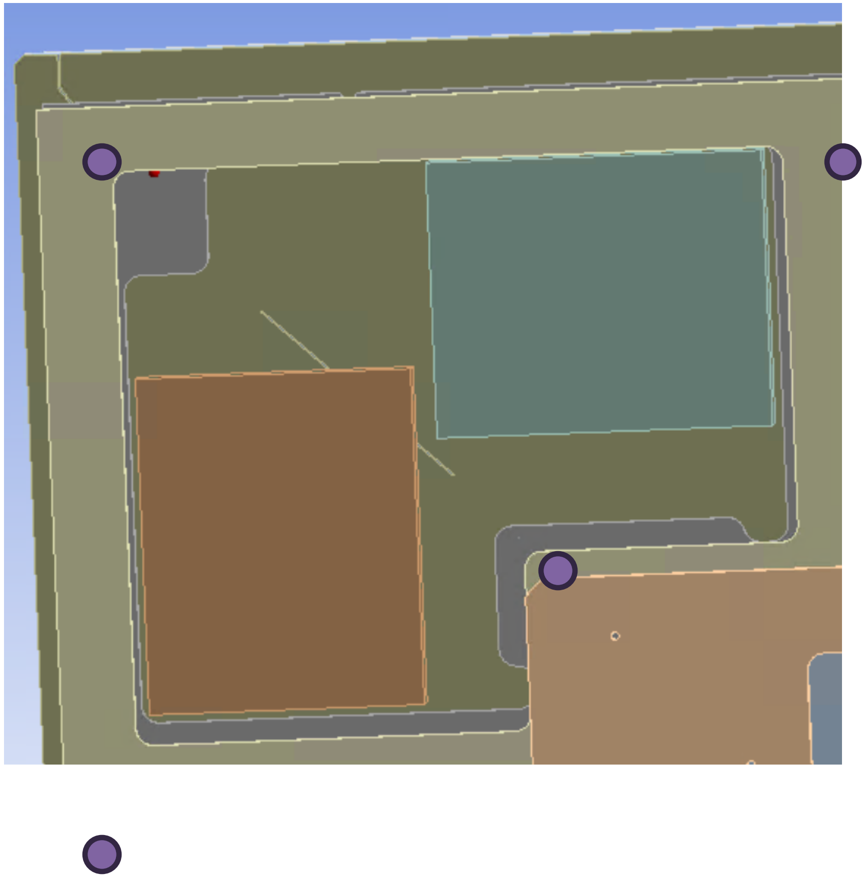
Stresses Experienced by BDE

- We can see from this image that the maximum occurs at a concentration point at a seem between BDEs.
- This location is at a corner where there are two FEMBs with relatively little material support.



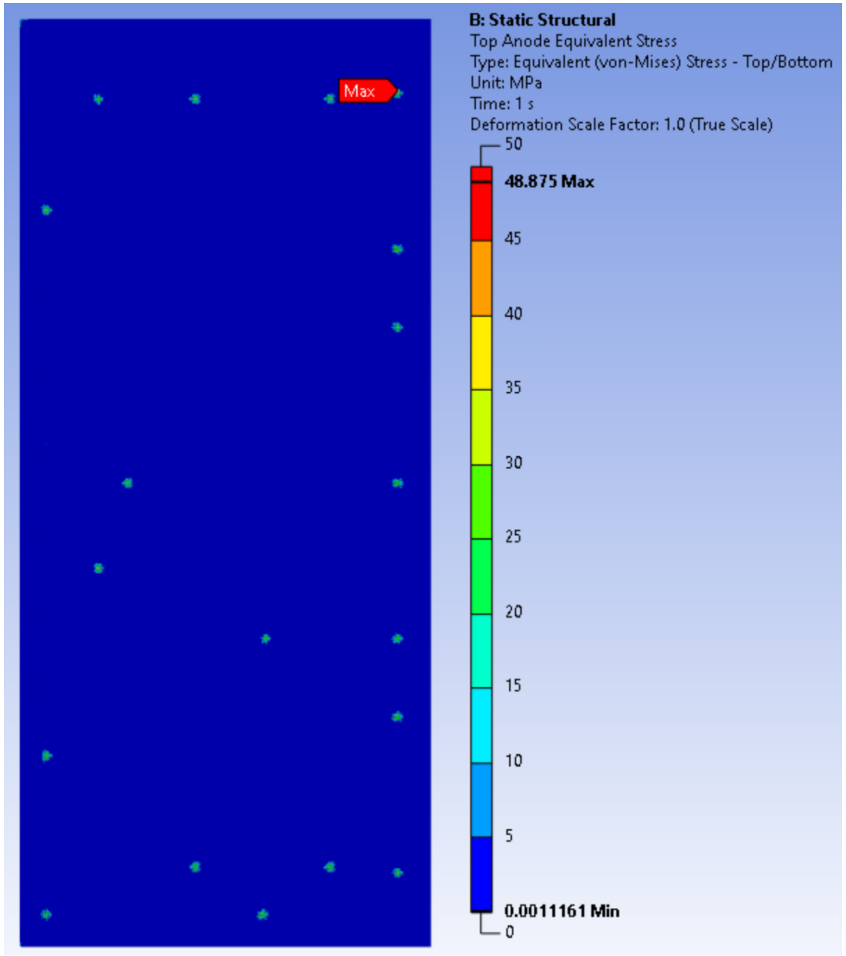
Geometry Near BDE Maximum

- Here there are the two BDE boards.
- The approximate positions of the nearest anode spacers are shown with the purple dots.



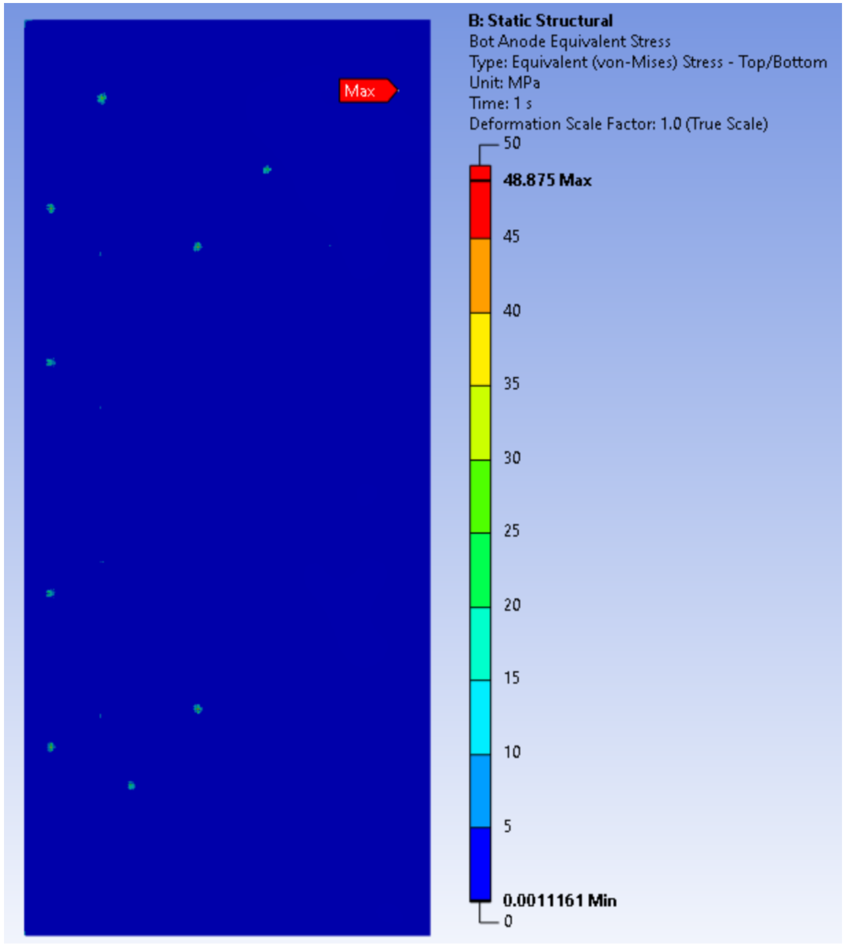
Stresses within Top Anode

- Maximum von Mises stress of 48.875 MPa.
- The greatest stresses occur at connections with anode spacers, closest to where the FEMBs are mounted.
- This makes intuitive sense and validates the result.
- Safety factor of 9.
- Integral average across the body is 0.4 MPa.



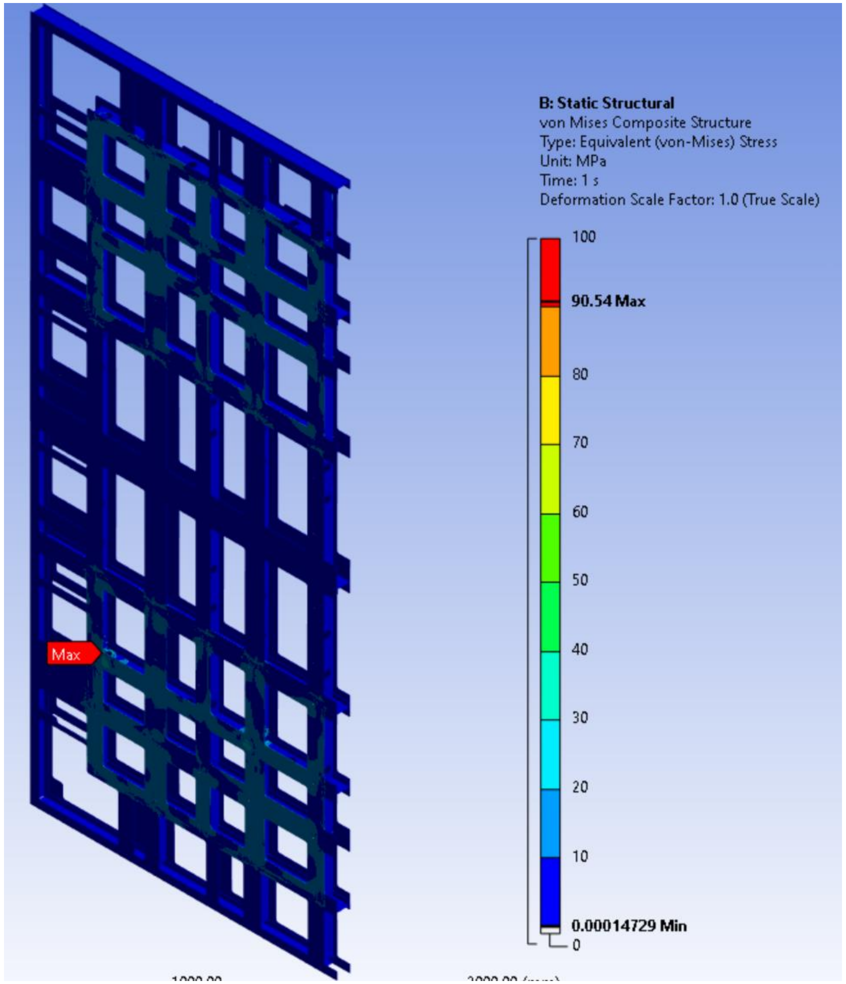
Stresses within Bottom Anode

- The maximum is the same as the top, 48.875 MPa.
- Similarly, the high spots are located at anode spacer supports.
- Same safety factor as top Anode.
- Integral average across the body is 0.34 MPa.



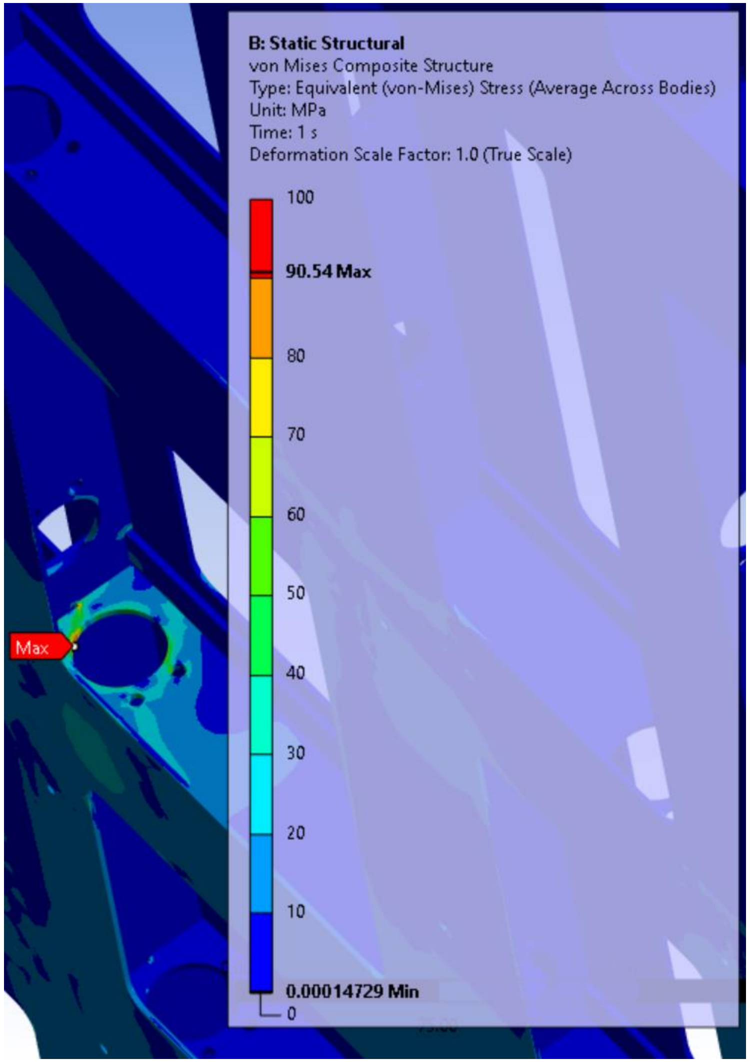
Composite Structure Stresses

- The overall state of stress is low relative to the yield strength (440.1 MPa).
  - The integral average state of stress is 2.66 MPa.
- The maximum occurs at a cable cutout within a composite beam near where this beam joins with one that is perpendicular to it.
- Other areas of concentration are where there is differential thermal contraction between the structure and G10 adapter plate.



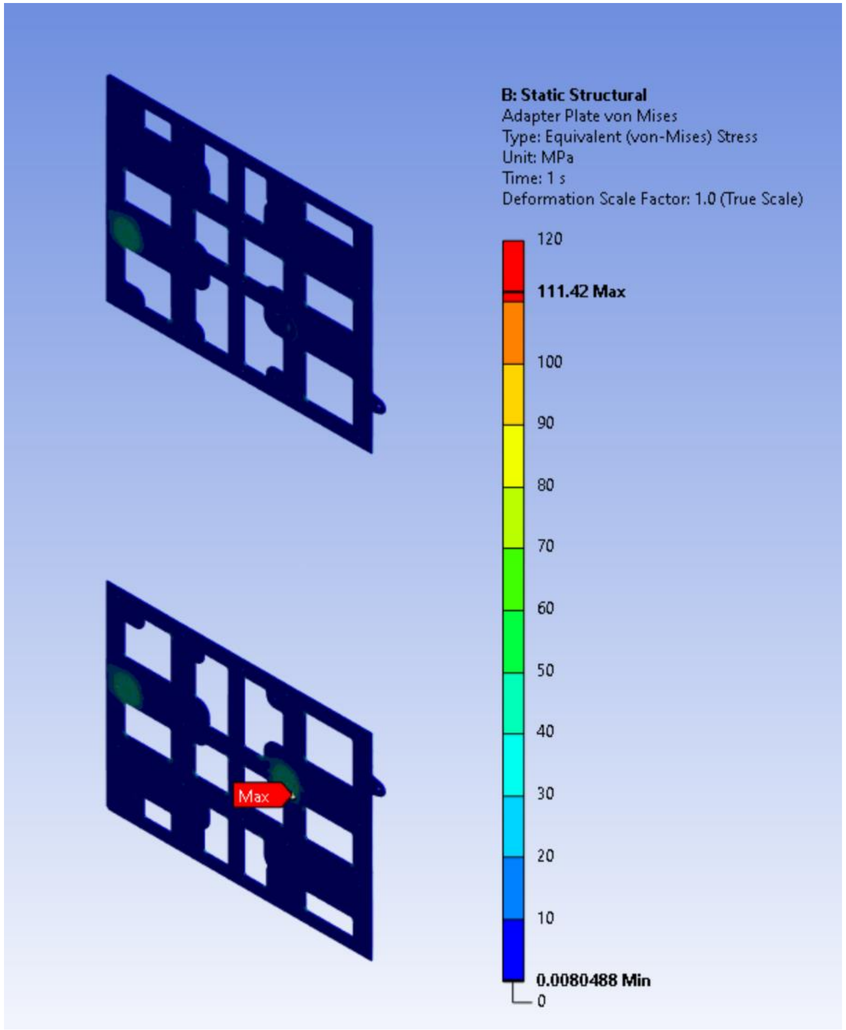
Local Maximum on Composite Structure

- The maximum stress is 90.54 MPa.
- Using this and the yield strength of 440.1 MPa we get a safety factor, 4.86.



Adapter Plate Stress

- Overall state of stress is low, 5.5 MPa.
- The maximum occurs at the contact surface between the fixed support and the adapter plate. This makes sense.
- Safety factor calculated using yield strength as 375 MPa is 3.37.



Summary of Results

Component	Material Yield Stress [MPa]	Maximum von Mises Stress [MPa]	Resulting Safety Factor [-]
Anodes	440.1	48.875	9
BDE Board	440.1	171.95	2.56
Composite Structure	440.1	90.54	4.86
Anode Spacers	90.9	33.695	2.70
Adapter Plate	375	111.42	3.56

Upcoming Work

- Model an adapter plate made from AISI 304 Stainless Steel.
  - Model two thicknesses 6.35mm (same as G10) and 4.7265mm.
    - Using M5x0.5 fasteners would give 9 full threads of engagement.
    - M5x0.8 would have almost 6 full threads of engagement in 4.7265mm thick plates.
  - This could save material cost if thread engagement is sufficient, and stresses are acceptable.
- 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.