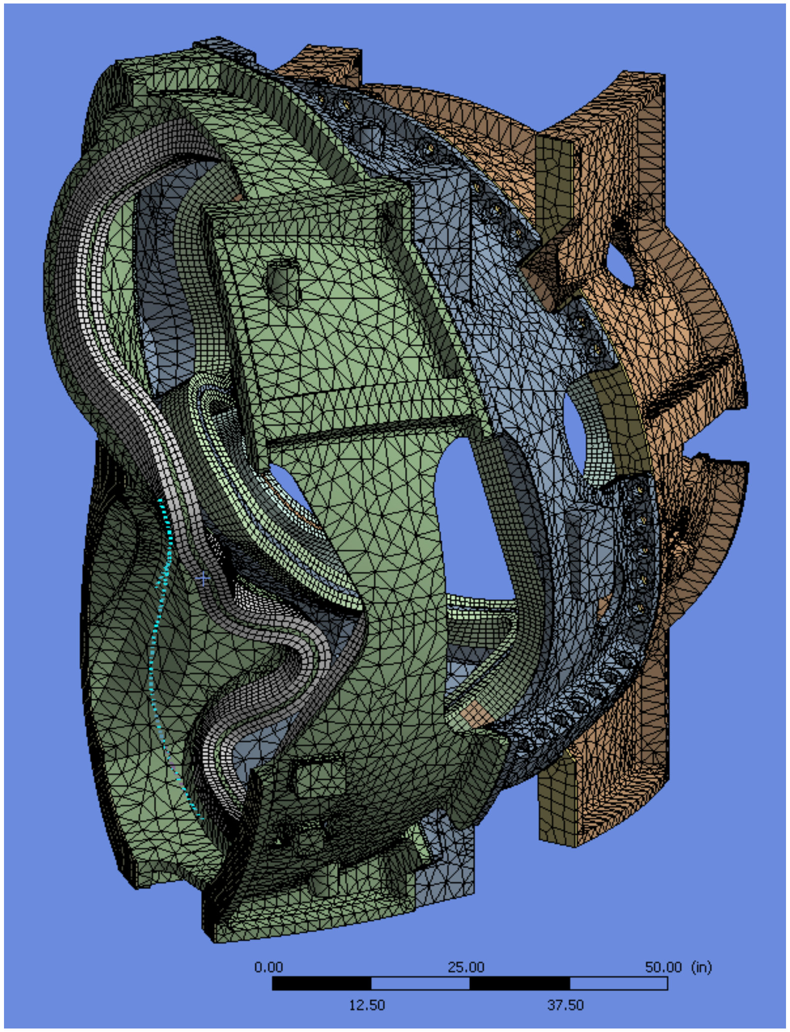
Modular Coil Analysis (with welds) and the CC bolt Connection schemes

6-18-07

New Global Model with weld on BC joint



Changes:

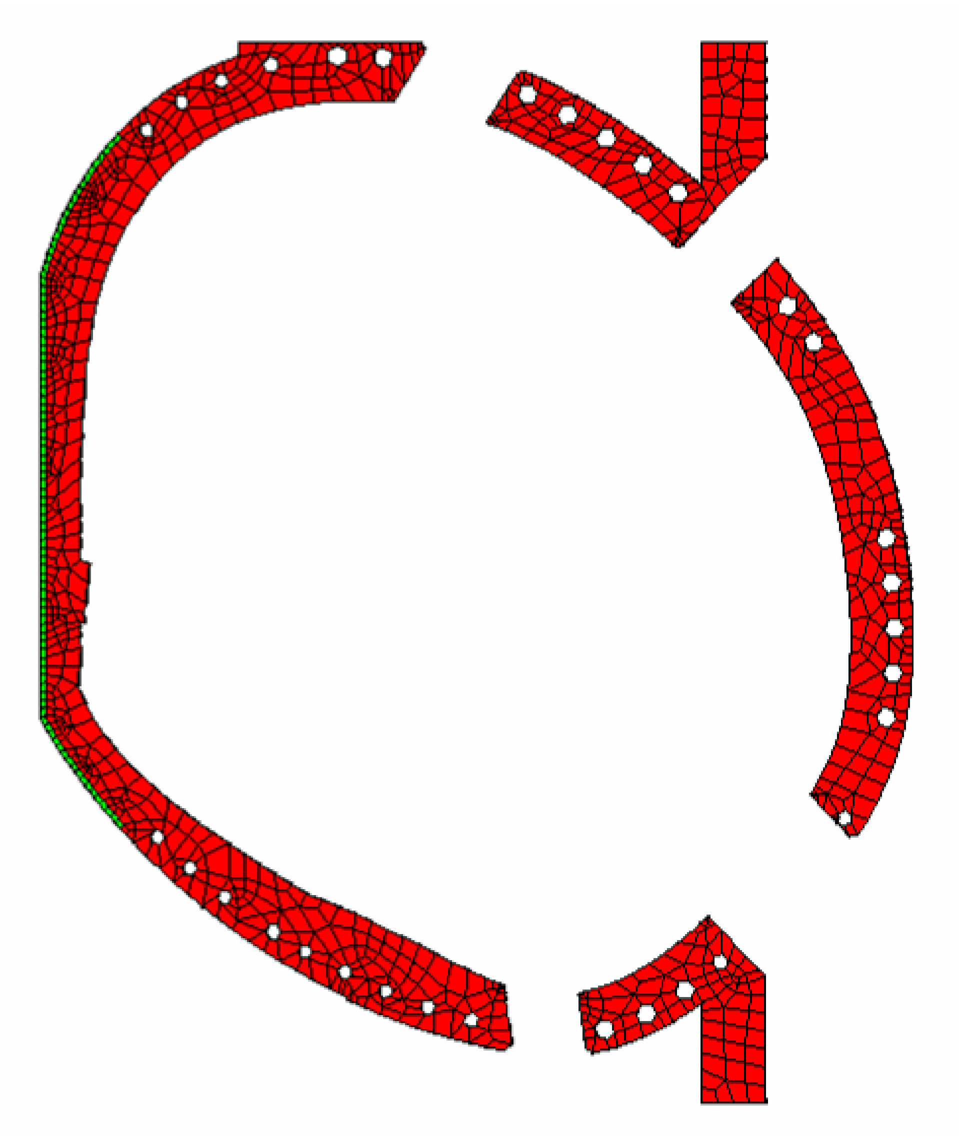
Bolt holes and bolts taken out of all flanges except the one of interest (BC). Allows us to add in bolts latter.

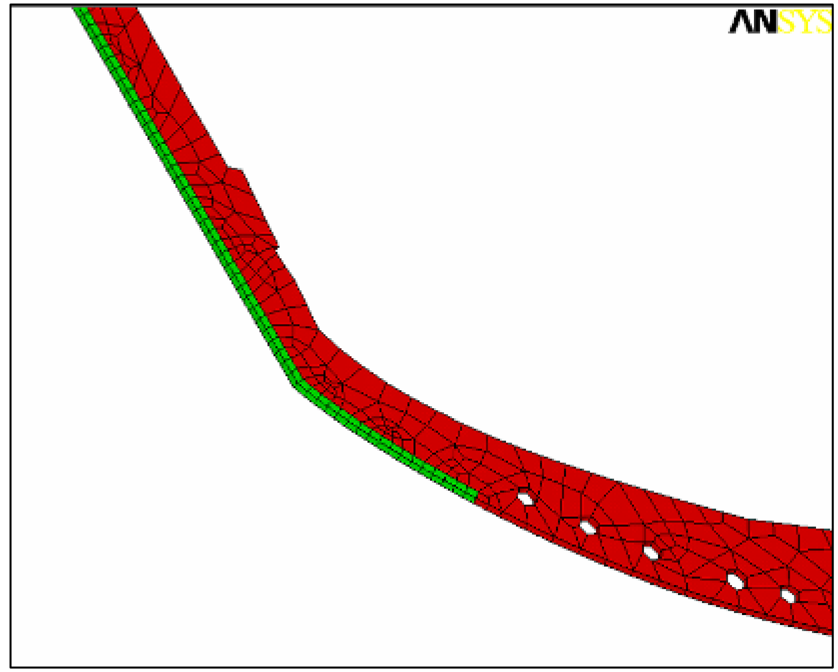
Weld Elements are placed in the model on the BC flange (see next slide).

Method will be to lock up the outboard side with bonded contact but have the inboard side run frictionless with the weld taking the shear and tension from the flanges..

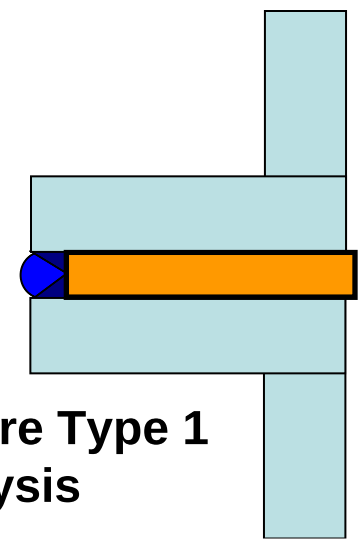
Material Props of weld match that of shim and castings

BC Flange (coarse global model)



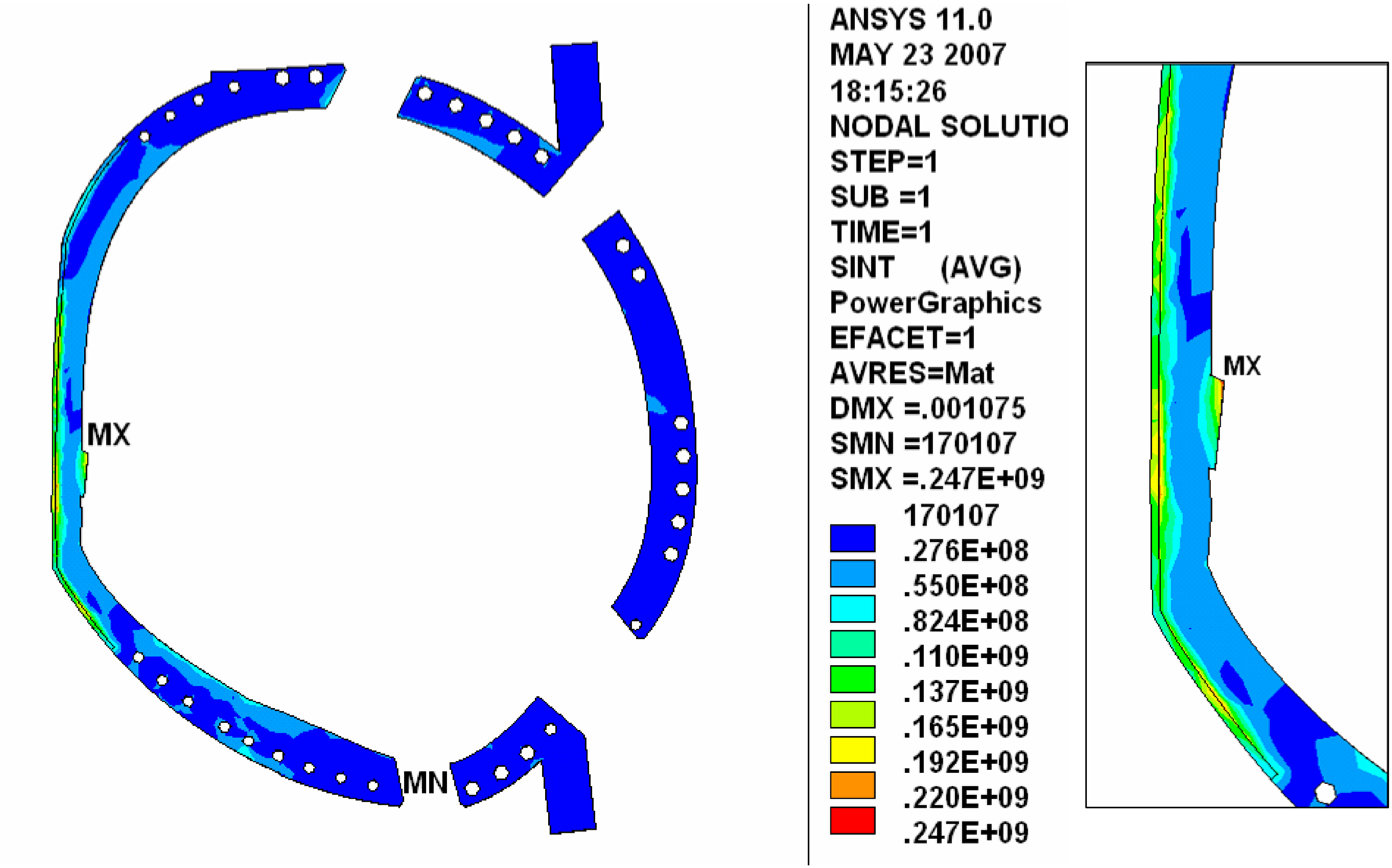


Weld is green elements are 20 node bricks.

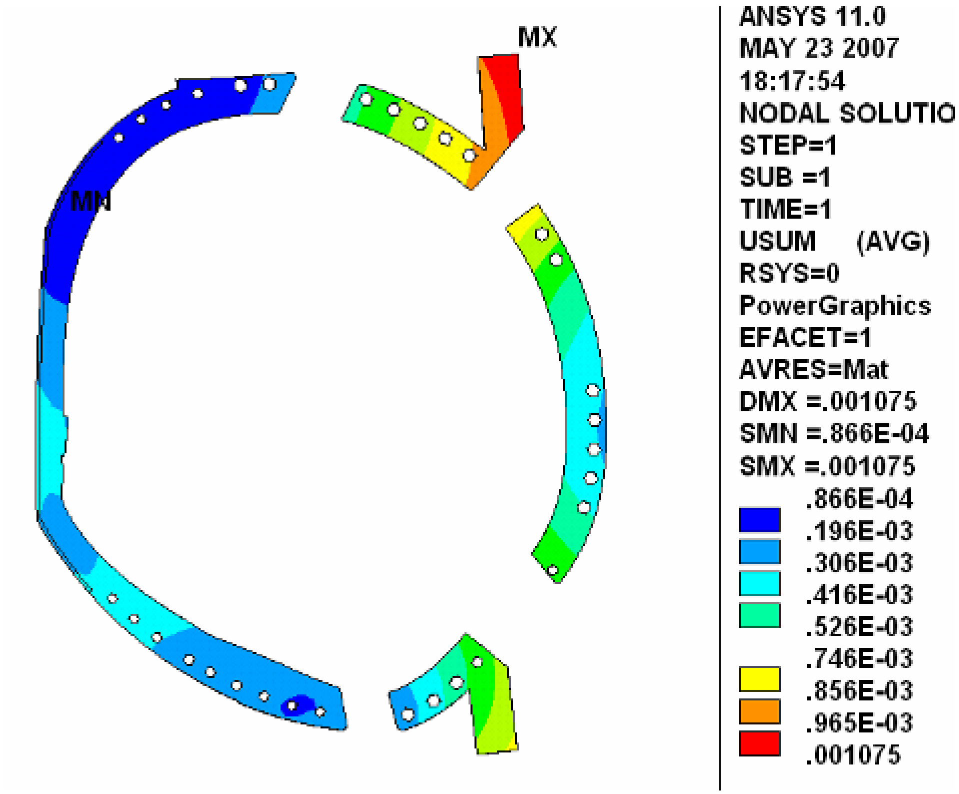


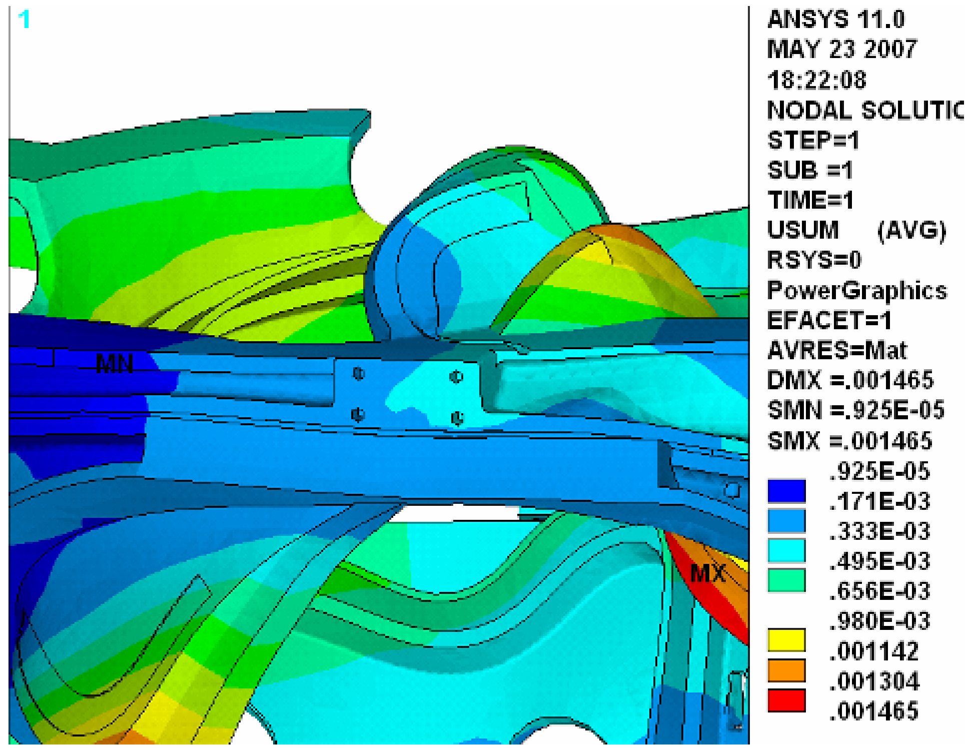
All welds are Type 1 in the analysis

Stress intensity (units are Pa)

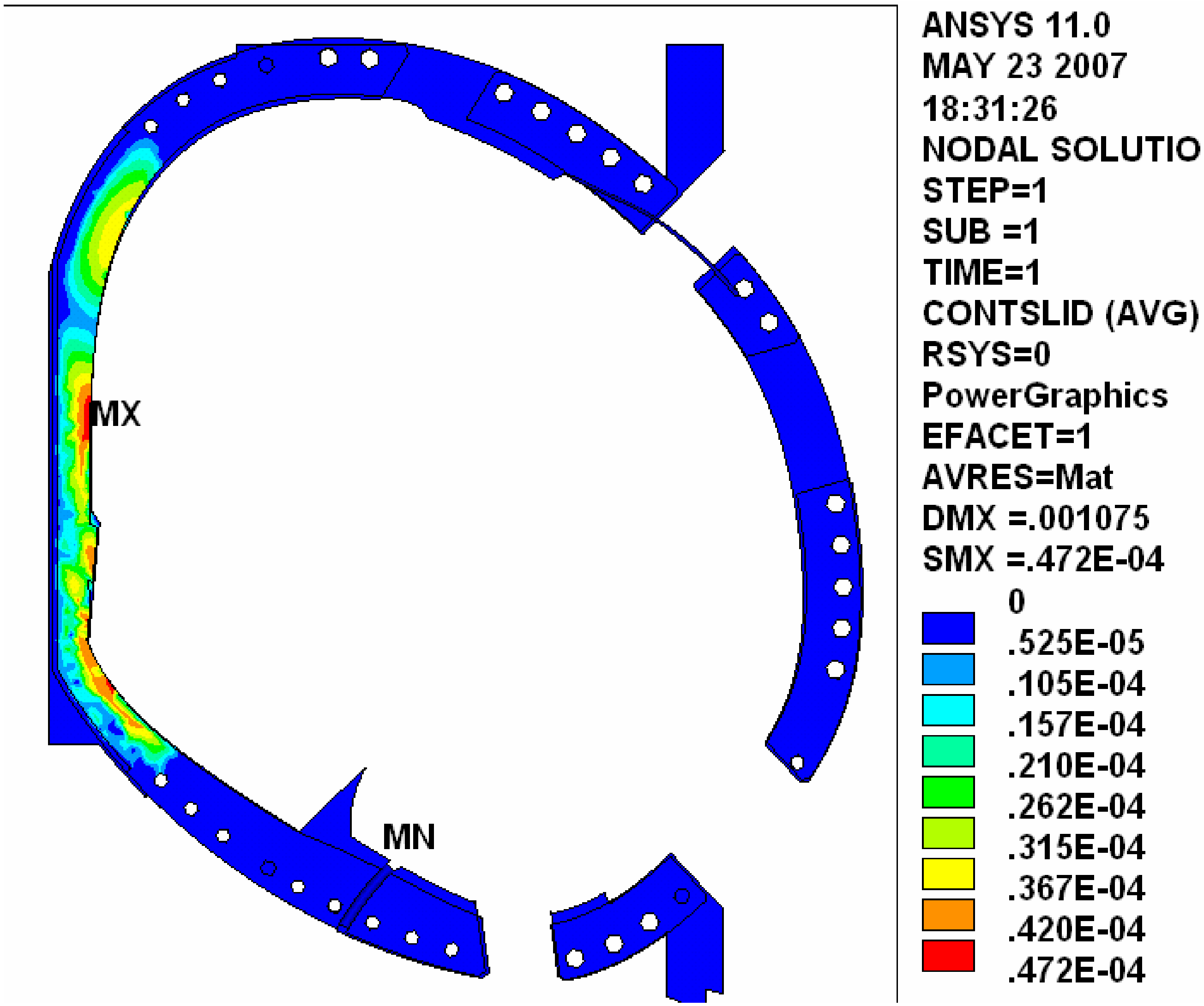


Deformations (global) (Units are meters)



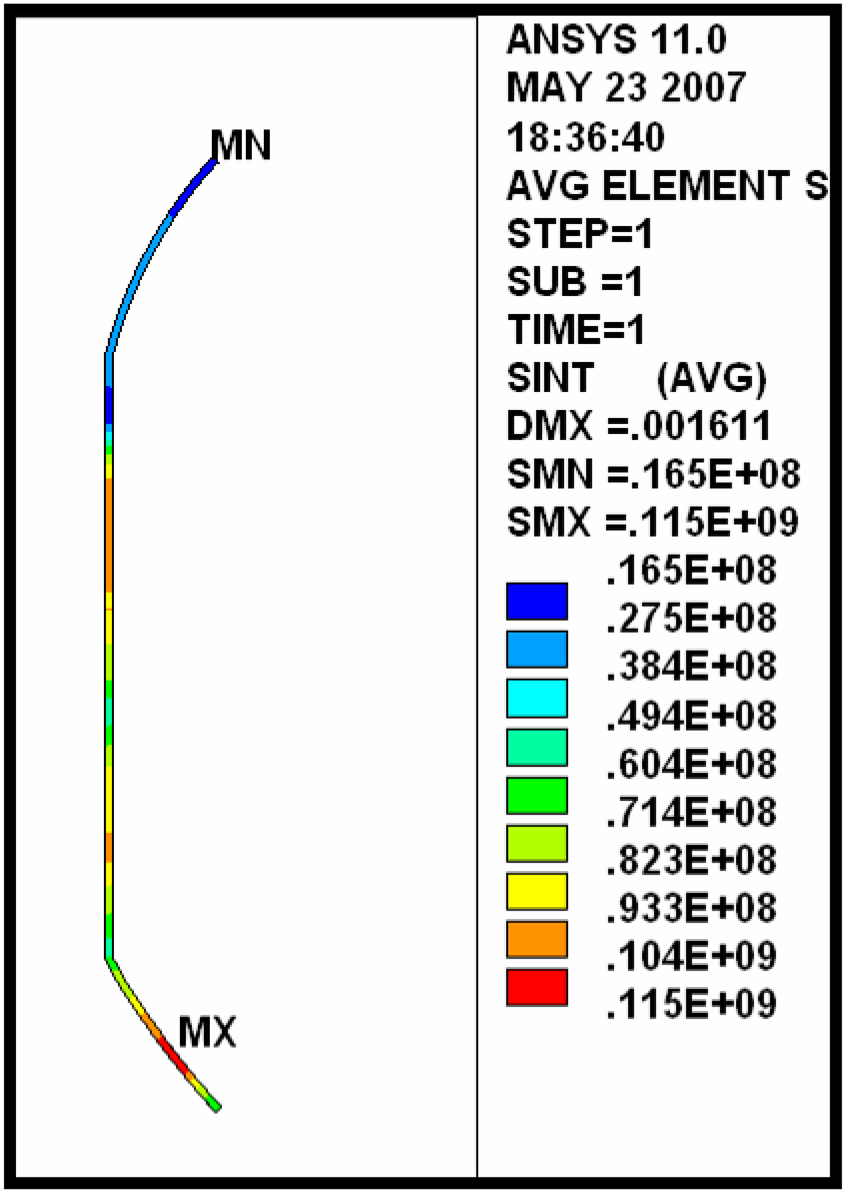


Contact Sliding (Units are meters)



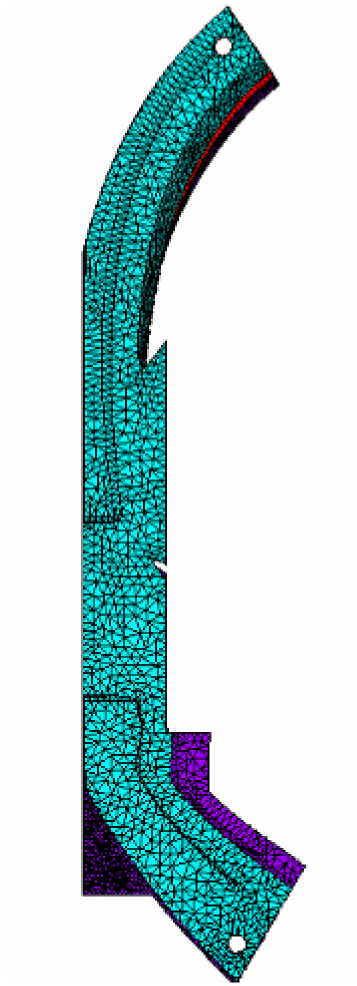
Peak sliding of .00185 in

Weld Stress intensity (Units are PA)

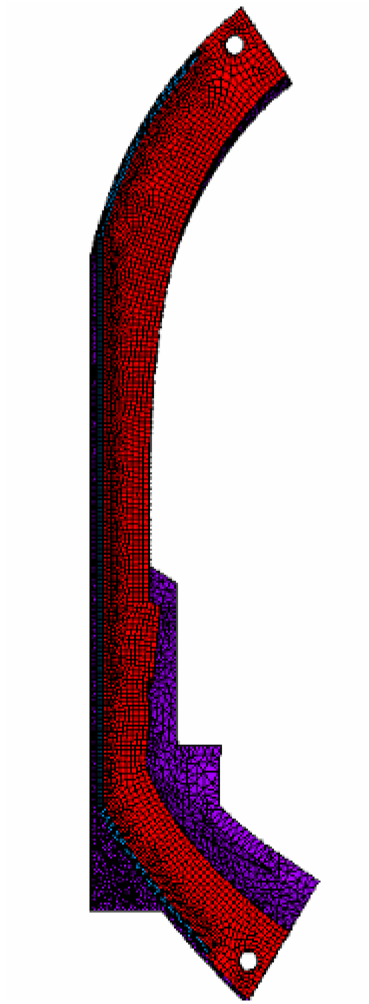


Peak Stress of 16,680 psi

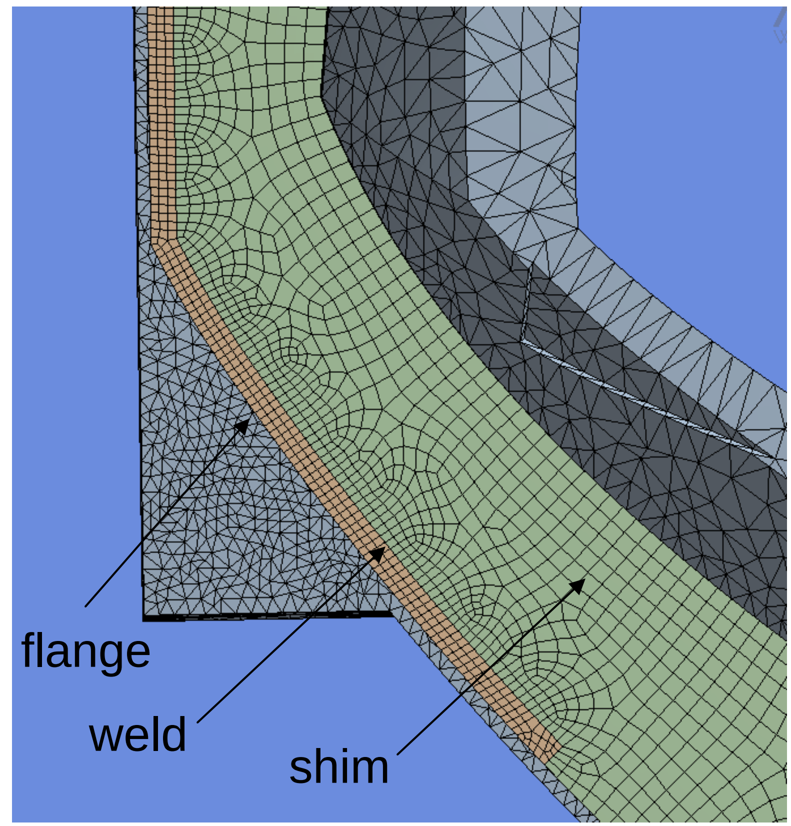
SUBMODEL [Mesh of inboard leg of BC joint]



Complete sub model showing both flanges



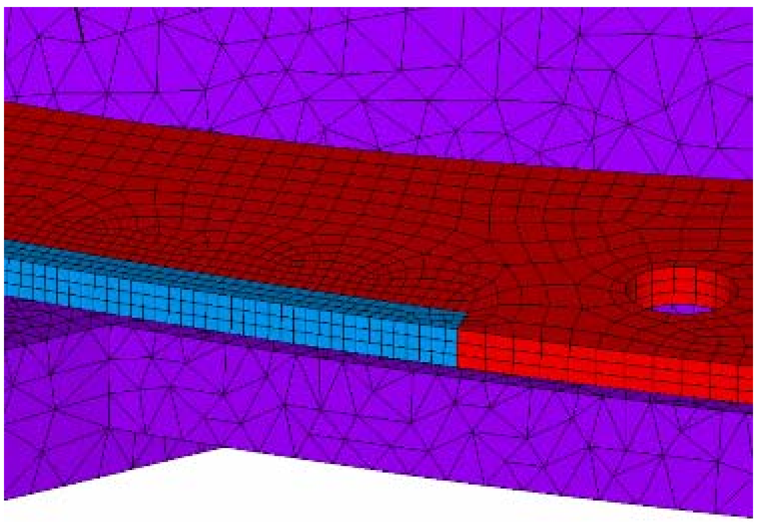
Flange B removed



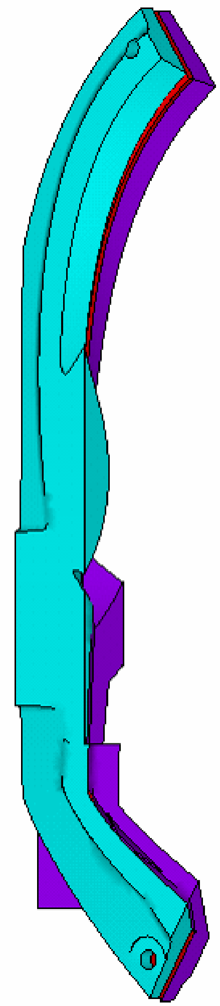
250,440 elements

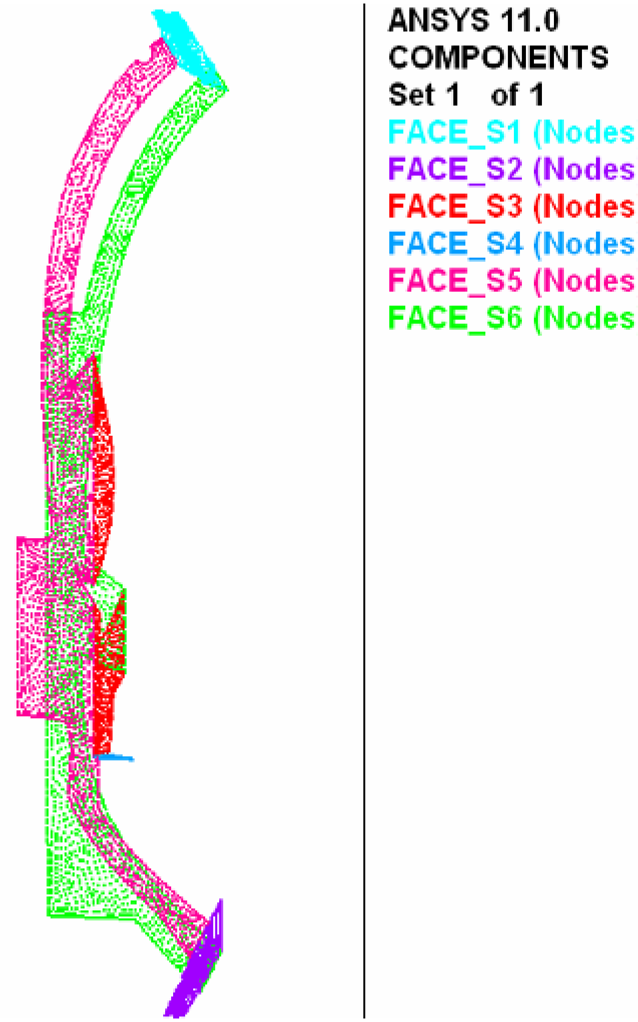
294,433 nodes

Nodes that map boundary conditions from global model



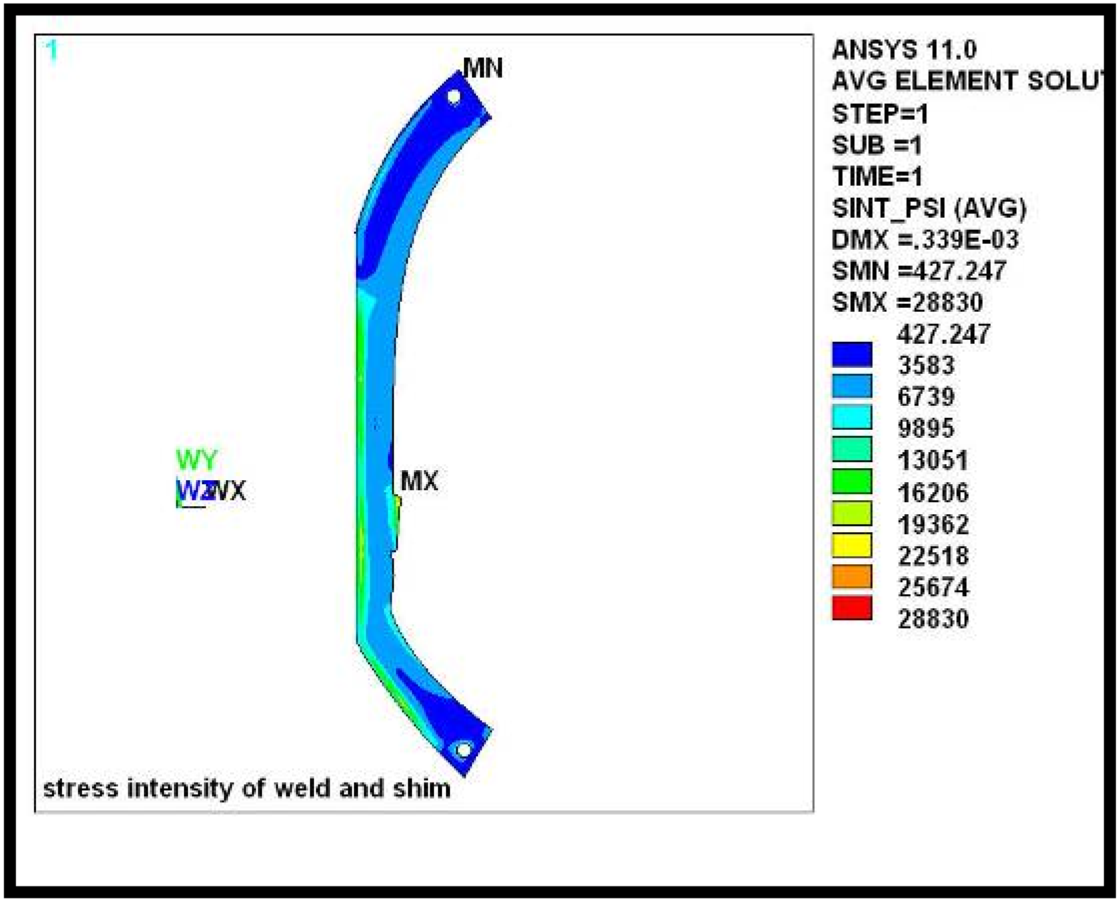
Mesh of weld is three elements thick, elements are higher order 20 node bricks.



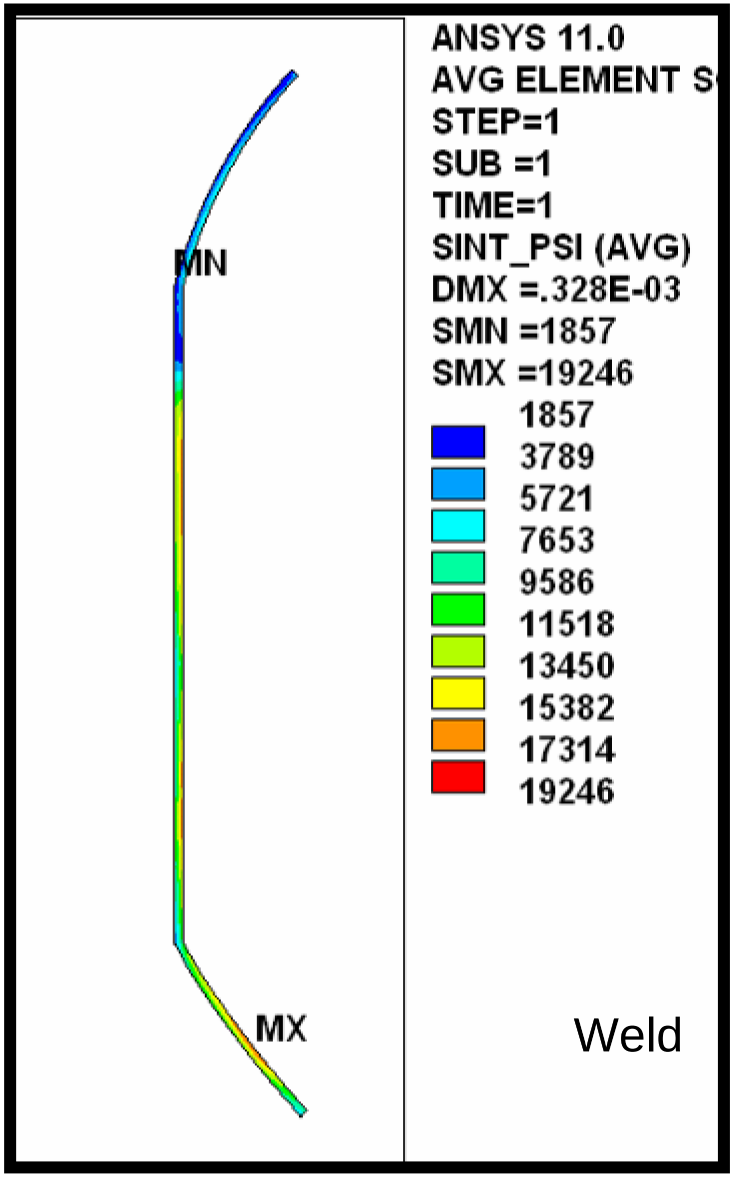


Faces of which displacements are mapped too in the global model

Stress Intensity of weld (Units are PSI)

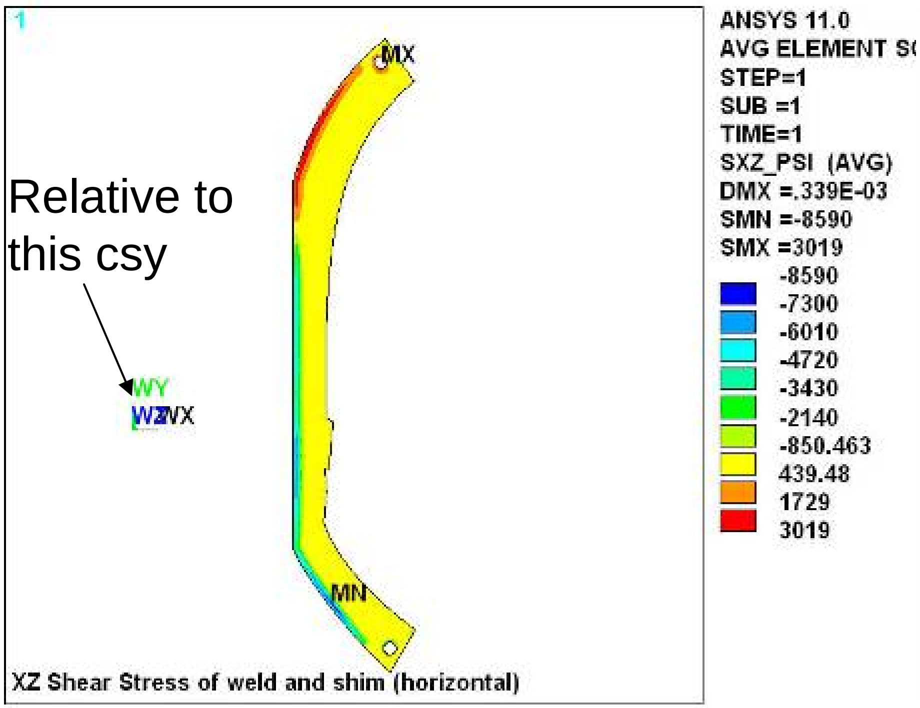


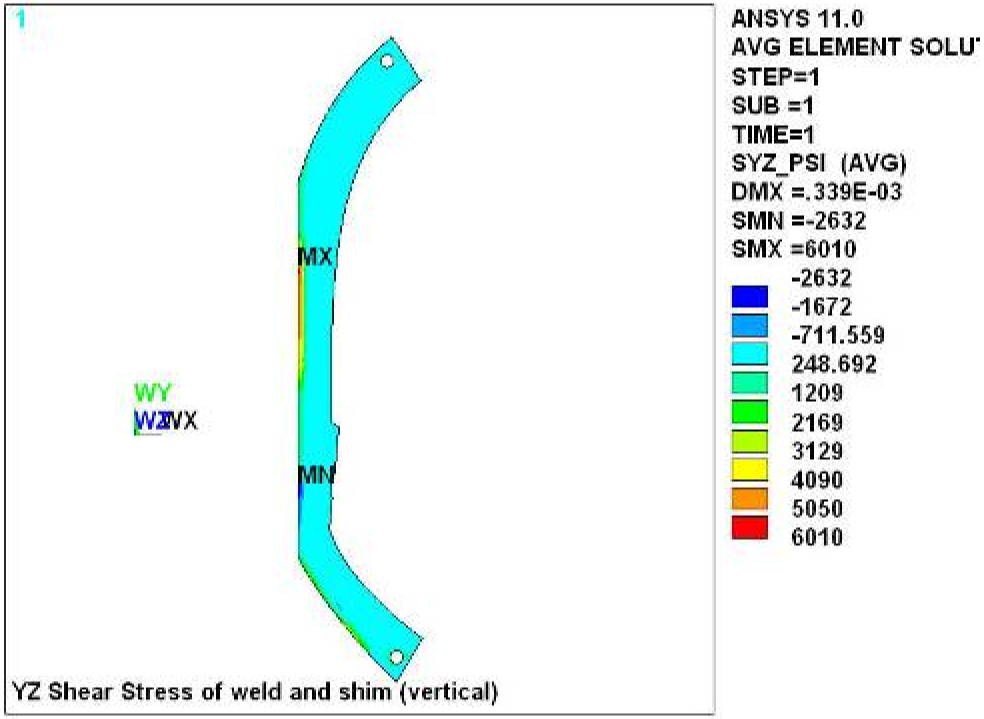
Weld and shim



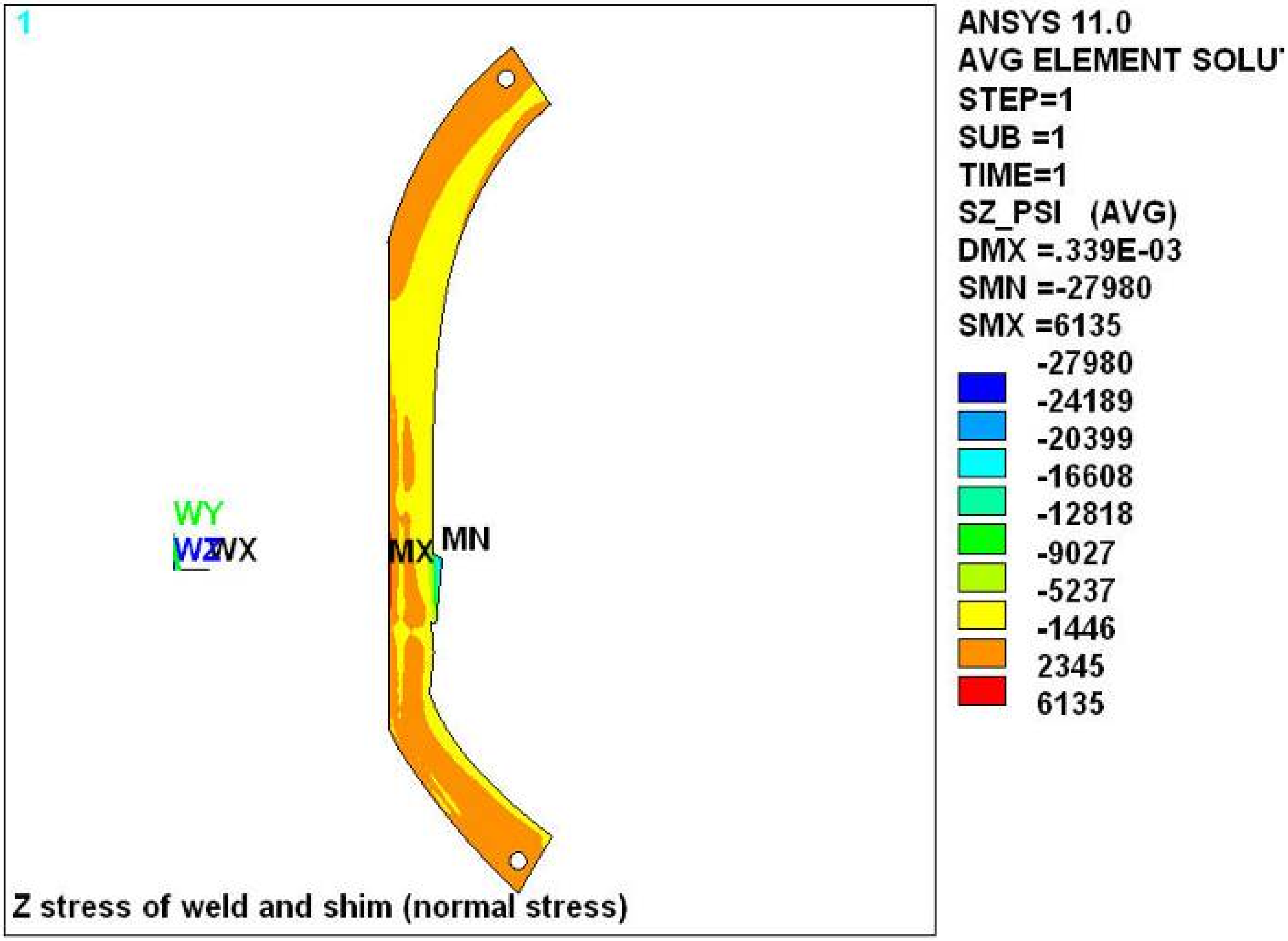
Weld

XZ and YZ Shear Stress of weld and shim (Units are PSI)

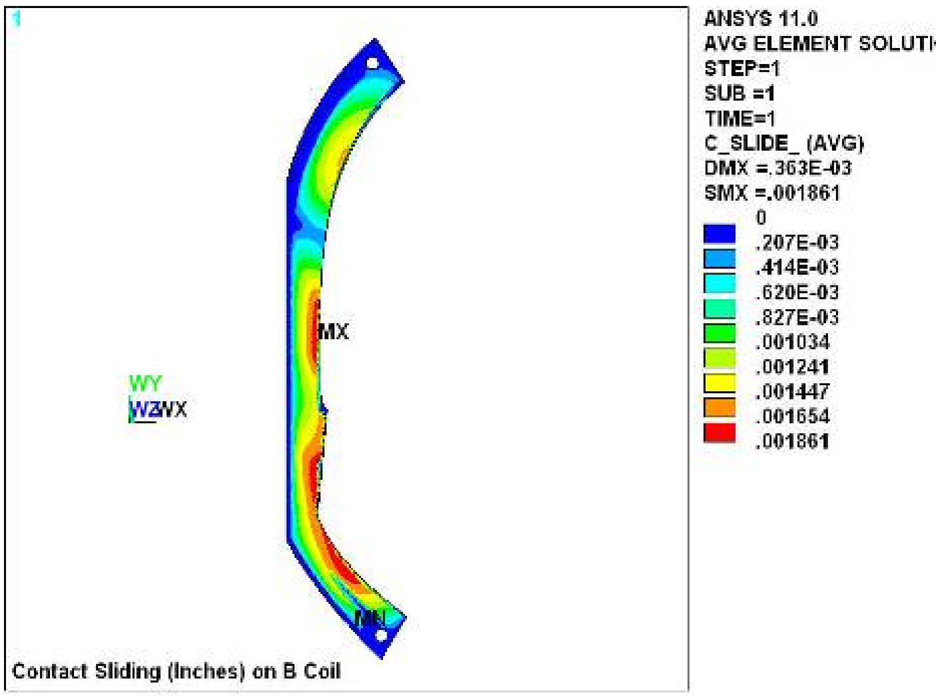


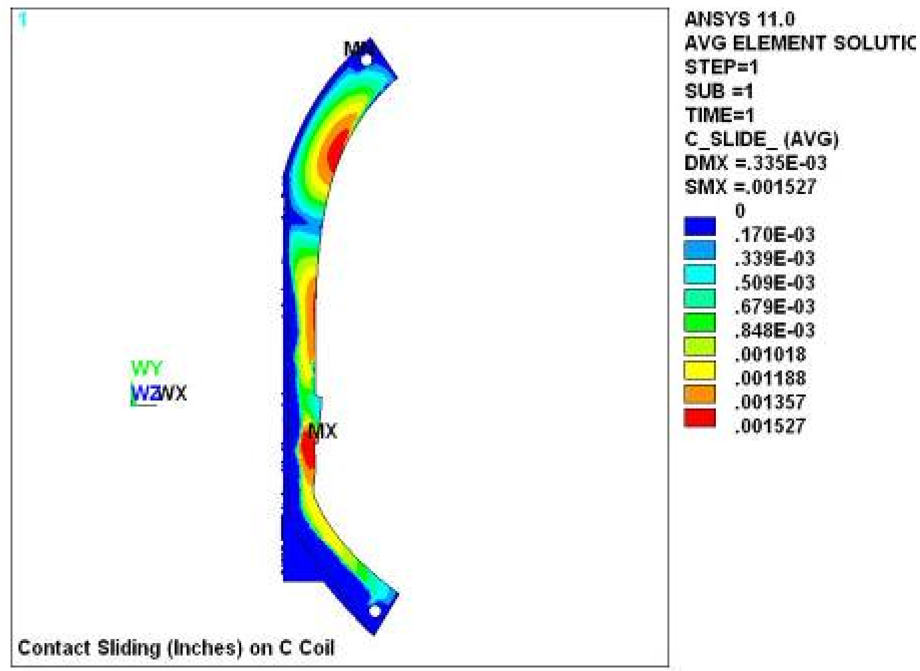


Normal Stress (Z) (Units are PSI)



Contact Sliding of shim on both flanges (inches)



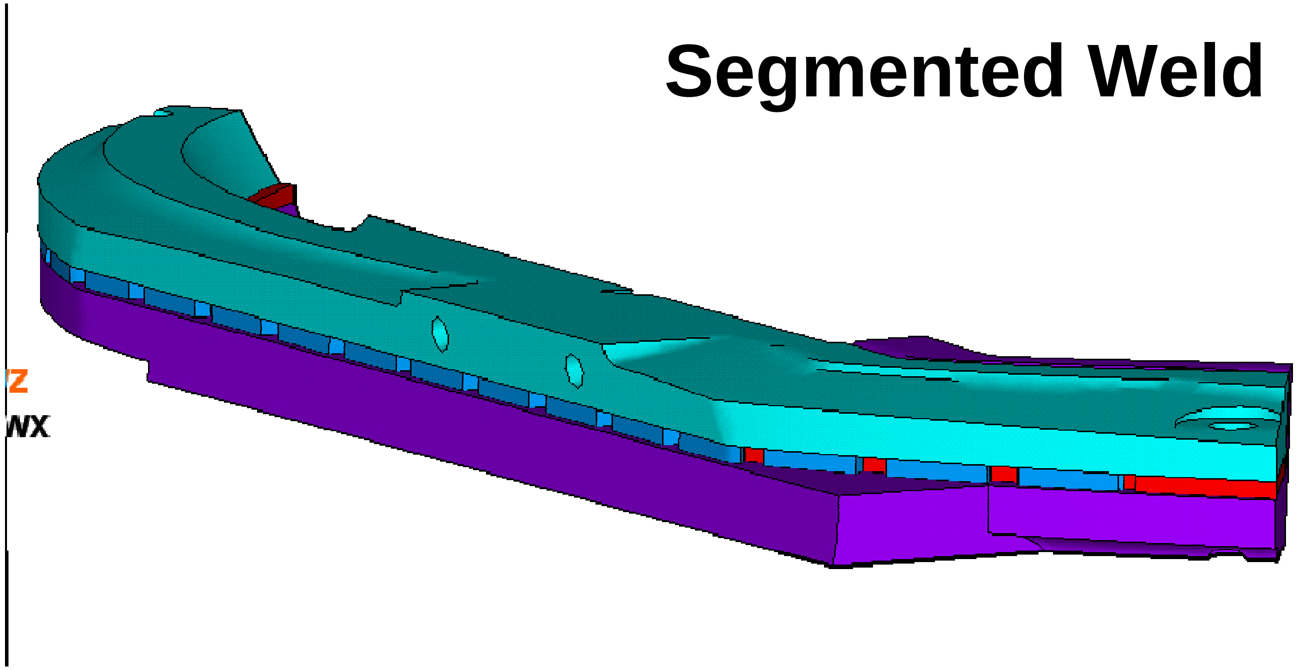


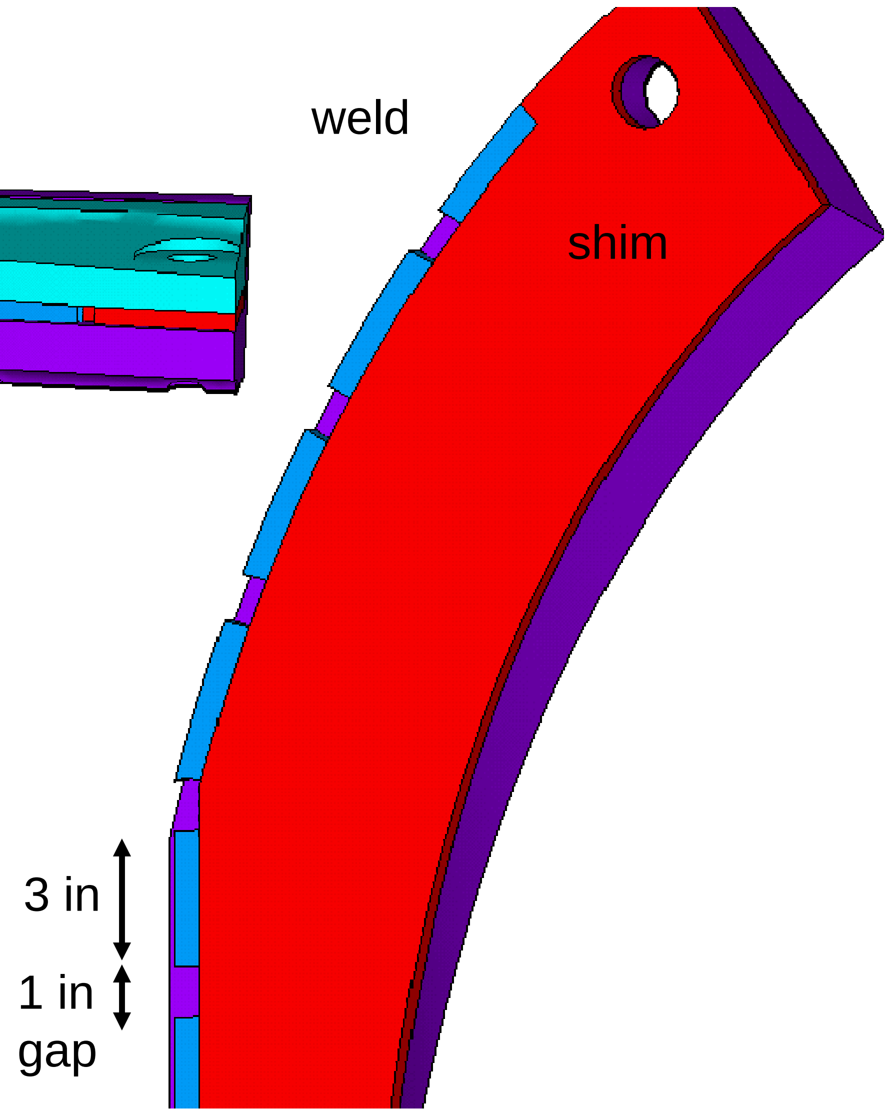
Quick weld allowable calculation based on BC weld

- Sm = 2/3 Sy at temp or 1/3 Sult for all materials
- Sy = 93.2 ksi for stellaloy but weld since Sult is 157.5 -> Sm = 52.5 based on weld wire.
- Knockdown factor of .6 applied for visual inspected welds. → **31.5 ksi**. Which is our max stress intensity we can incur.

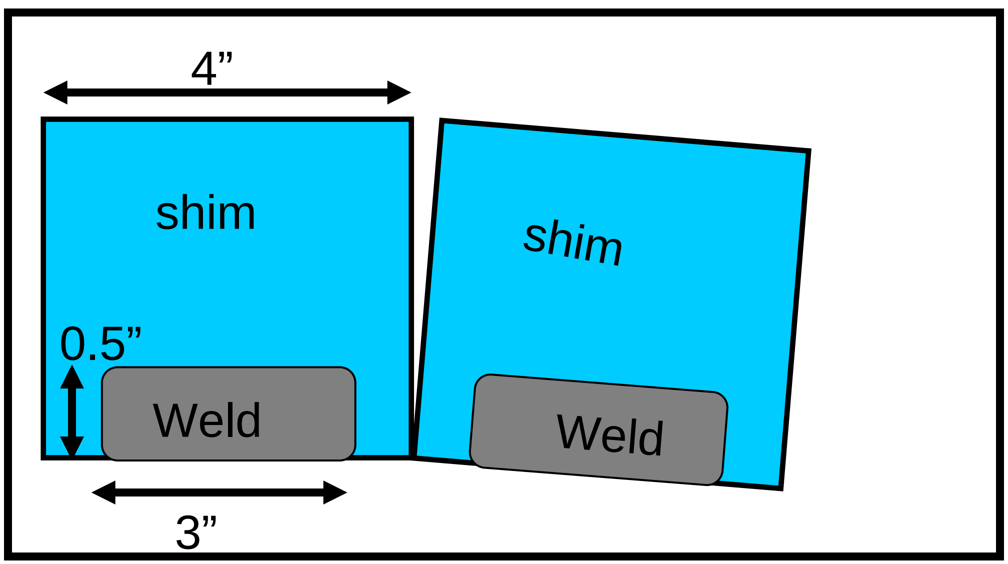
- Max stress Intensity from our Model is **19.2 ksi**.
- Fatigue remains an issue

Segmented Weld

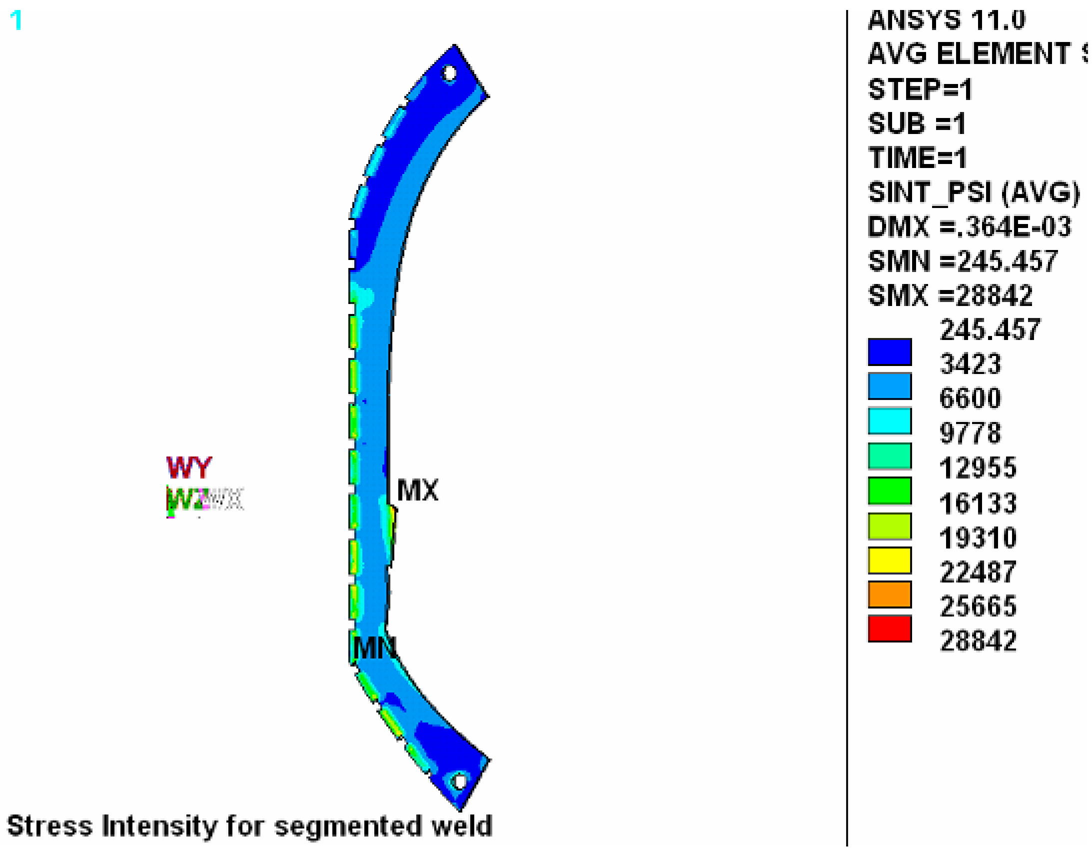


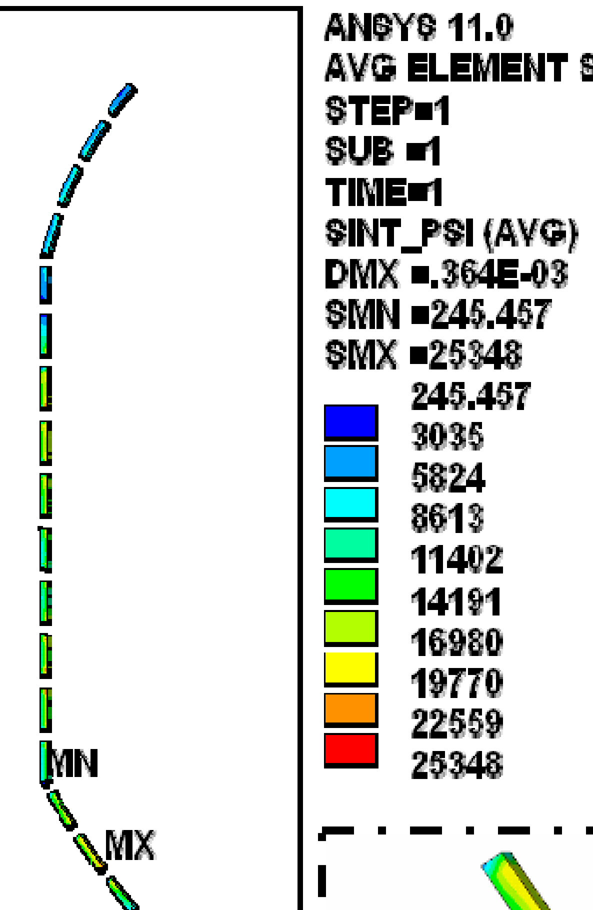


Weld shim sketch

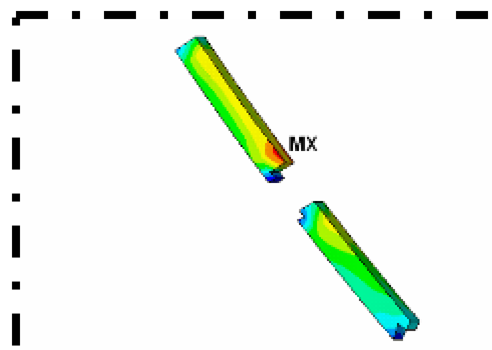


Stress Intensity with segmented weld (0.5”) (Units are psi)



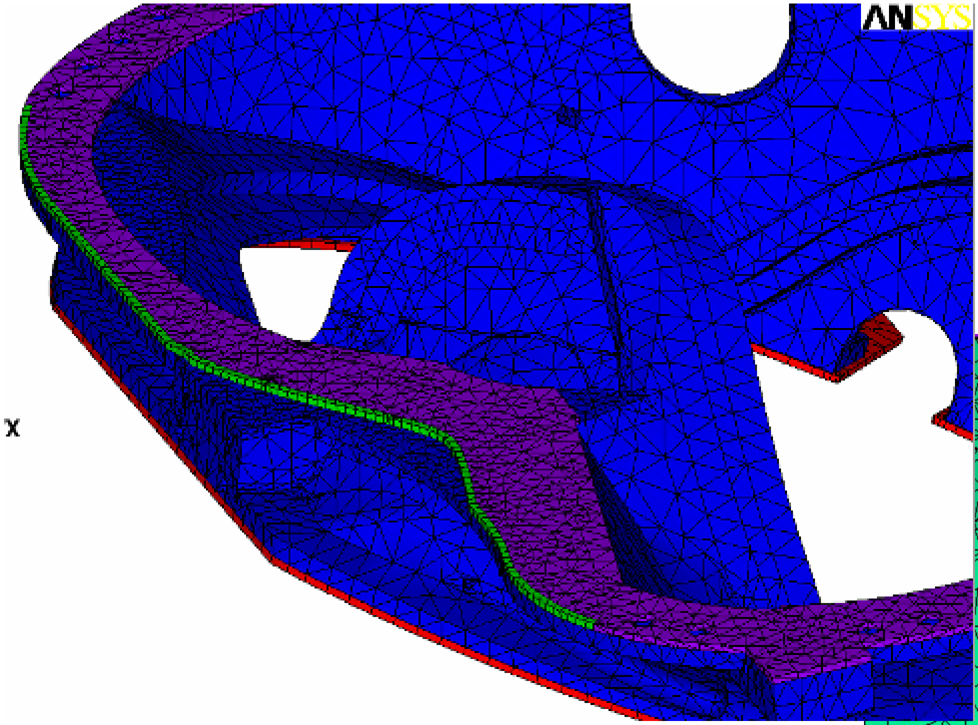


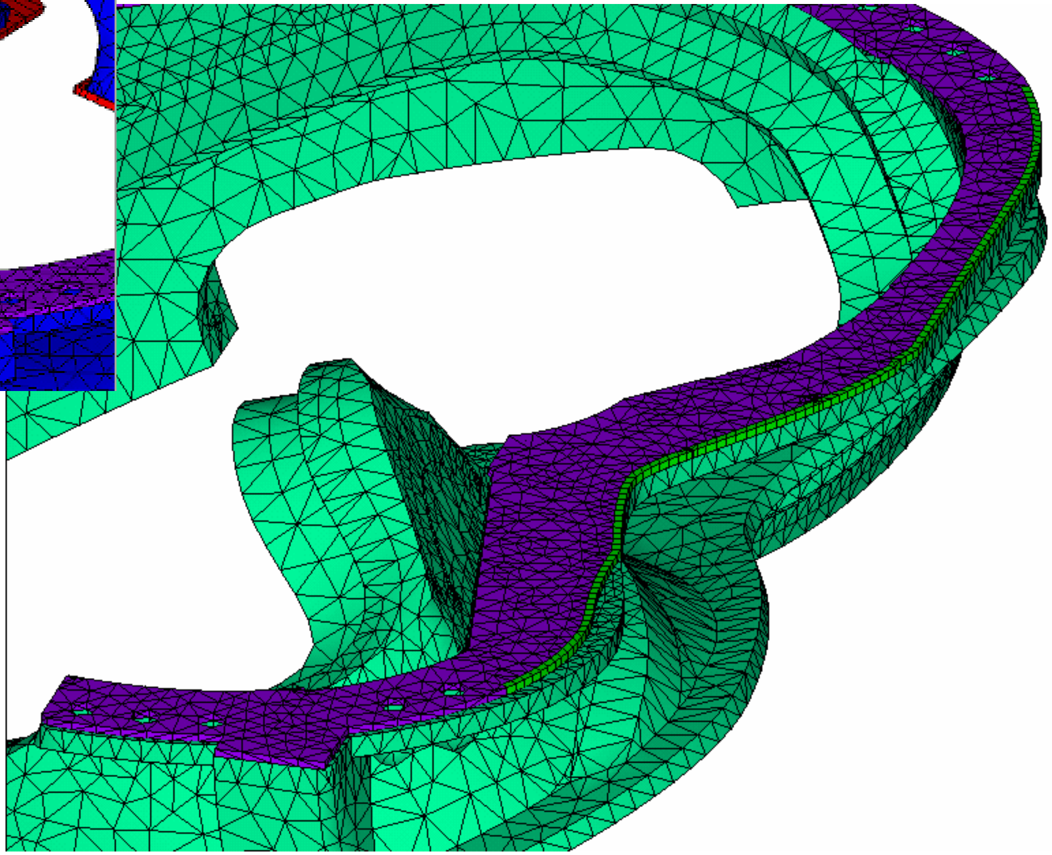
Segmented weld



Stress Increases from 19.2 to 25.3 ksi with added segmentation

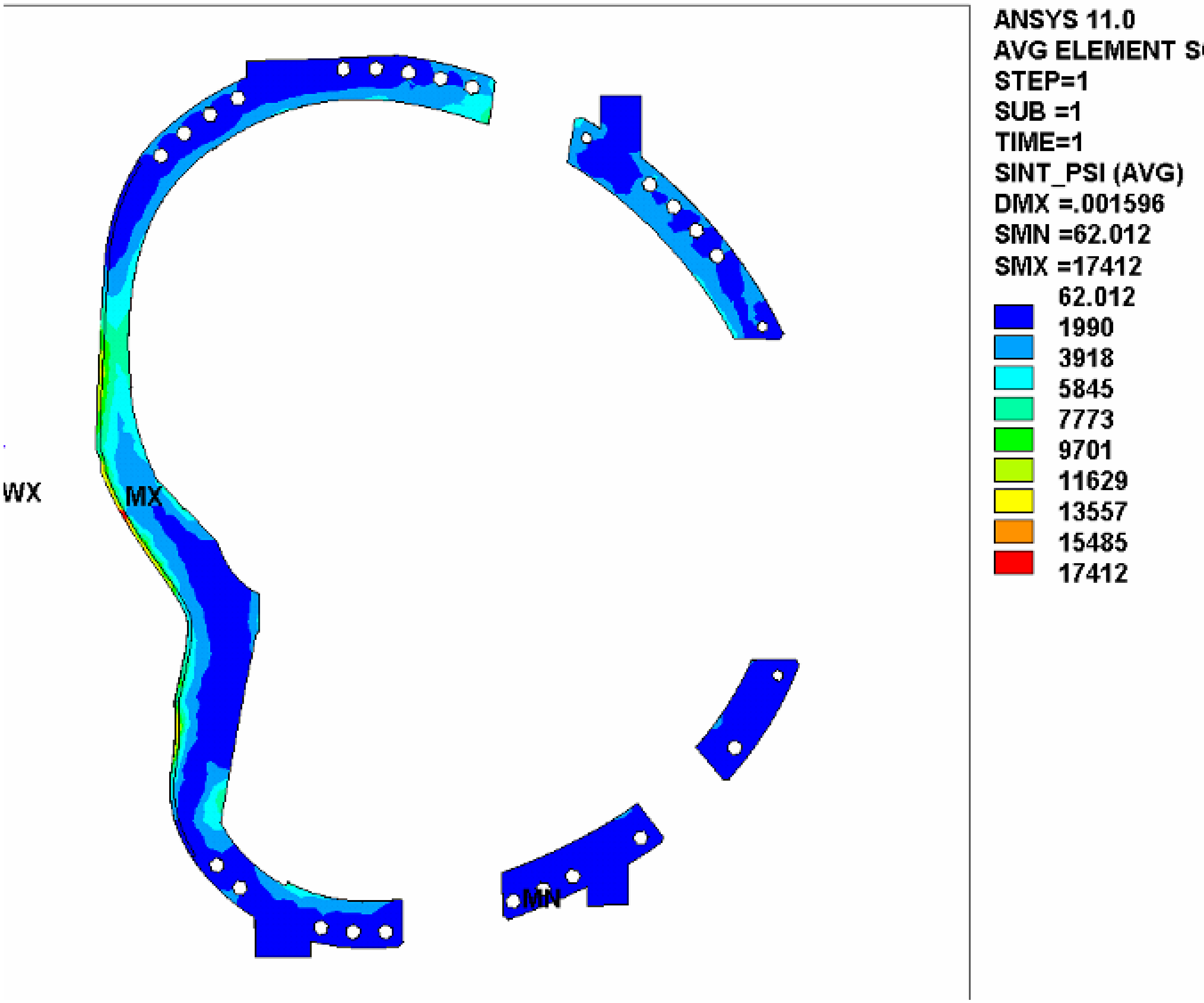
AB Weld model (same method as BC)



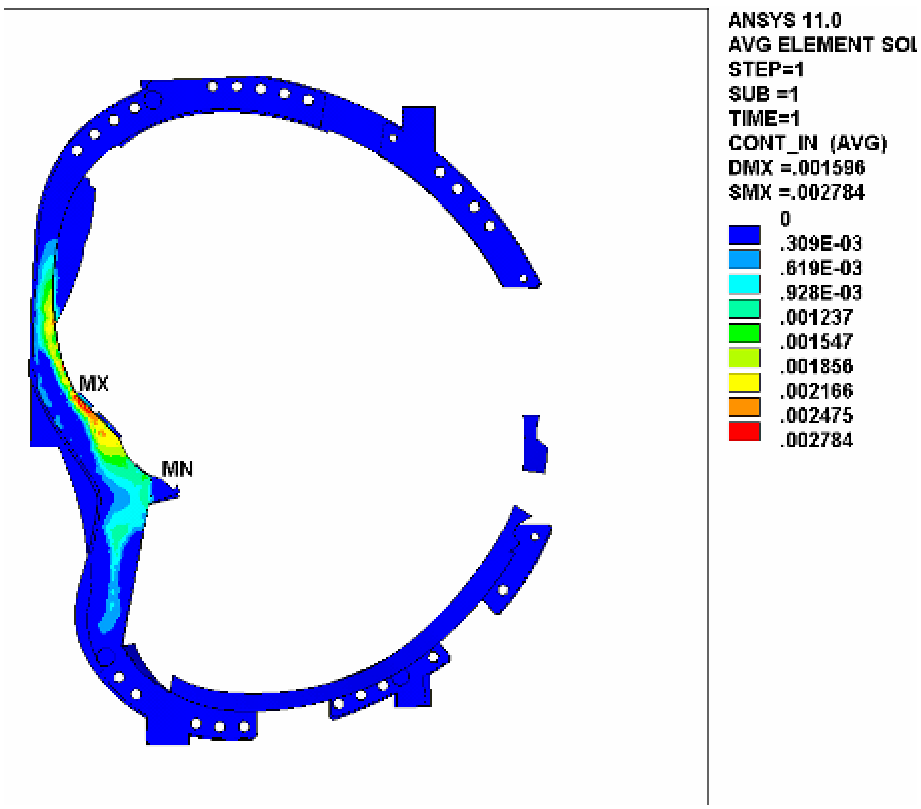


One line of elements 0.5” thick

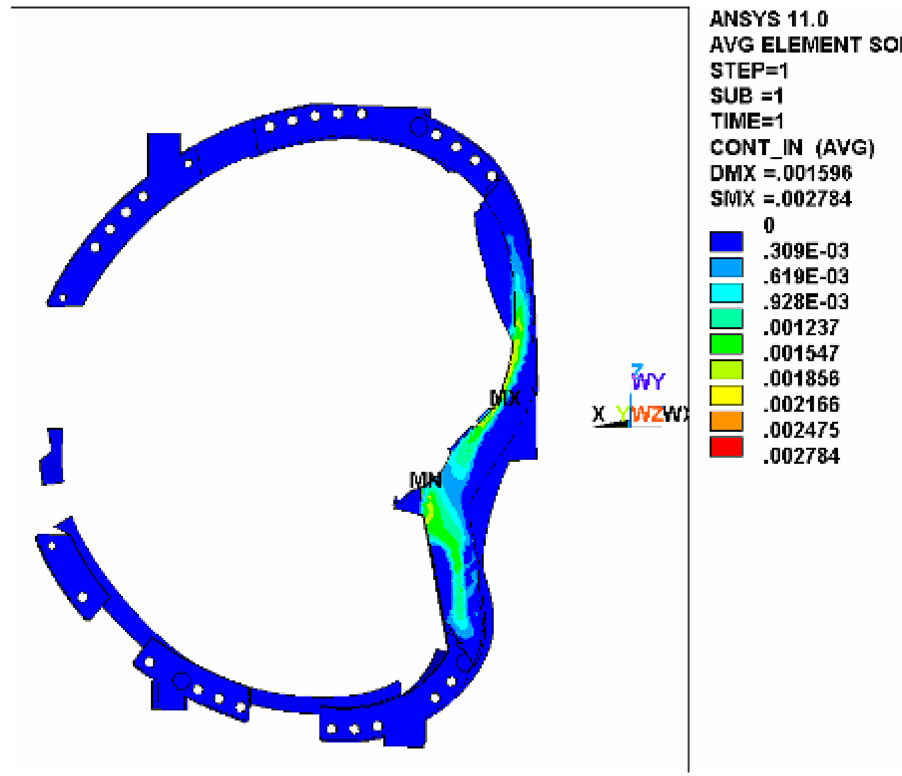
Stress Intensity of Weld and shim (units are Psi)



Sliding (Units are inches)

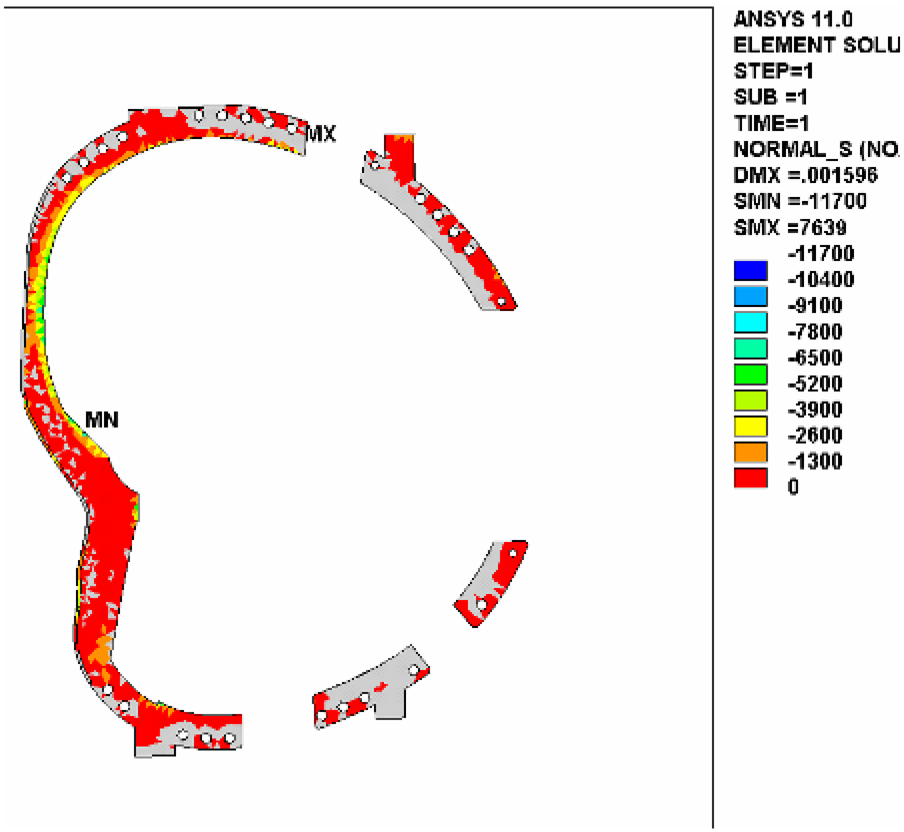


Looking from A

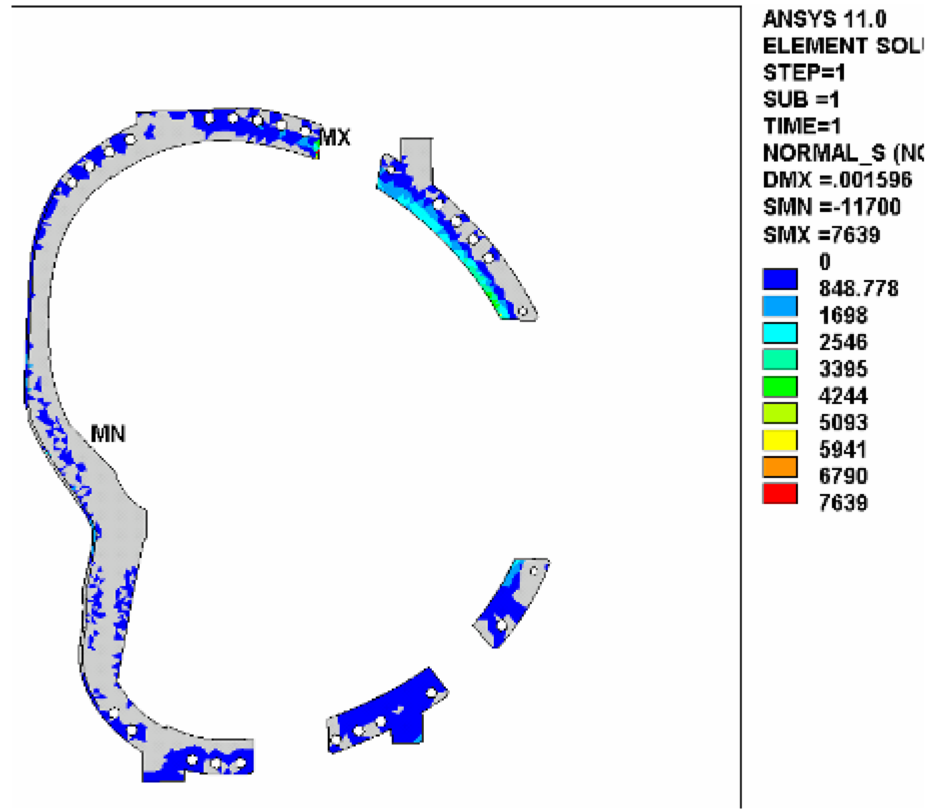


Looking from B

Normal Stress (Units are psi)



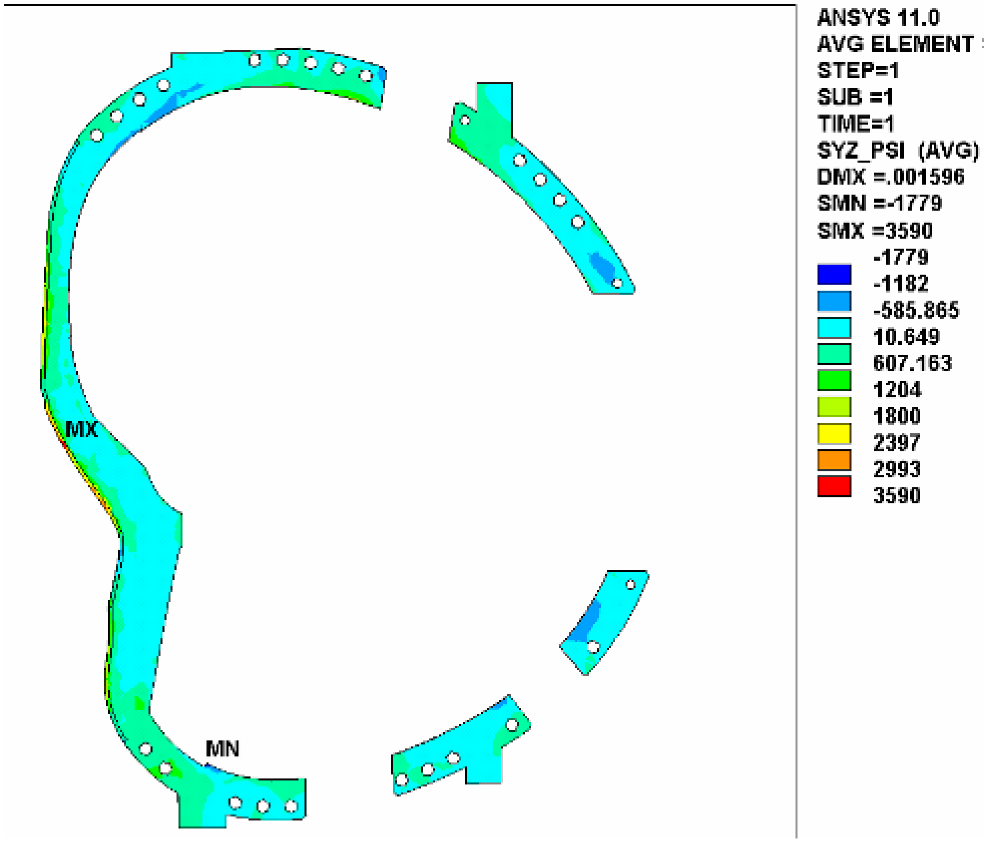
Grey = tension



Grey = compression

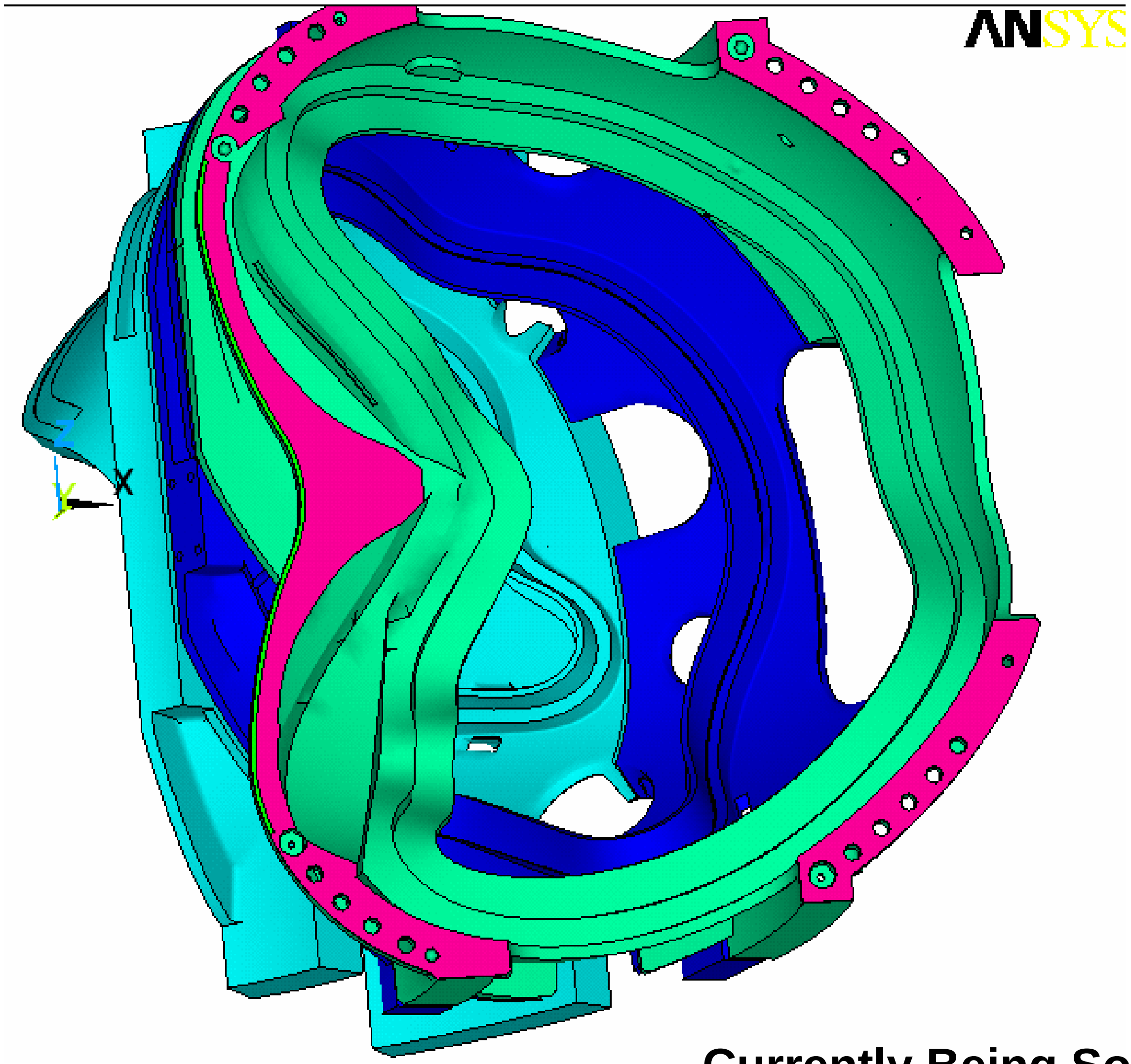
Shear Stresses (psi)

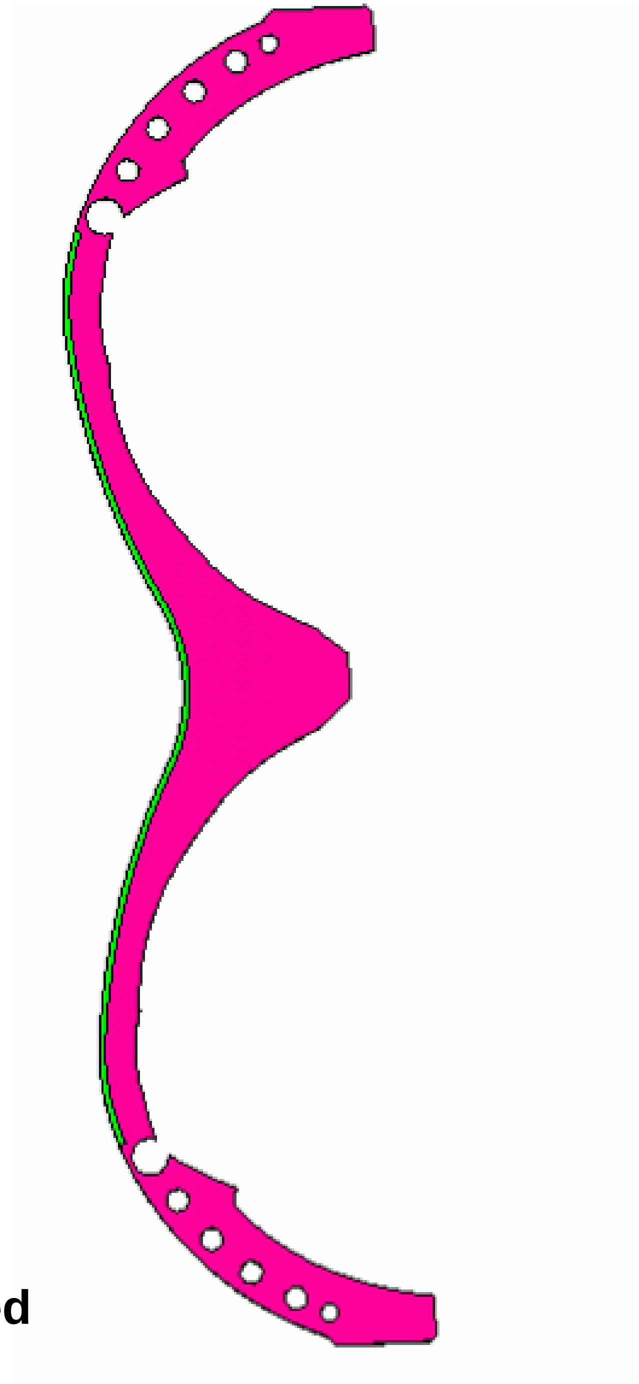
SXZ (horizontal shear)



SYZ (vertical shear)

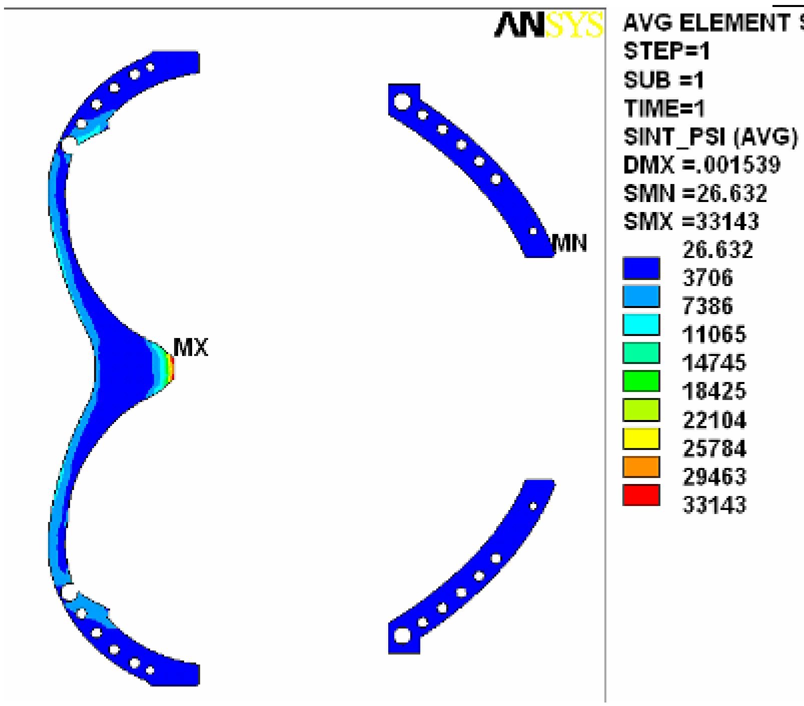
AA Weld



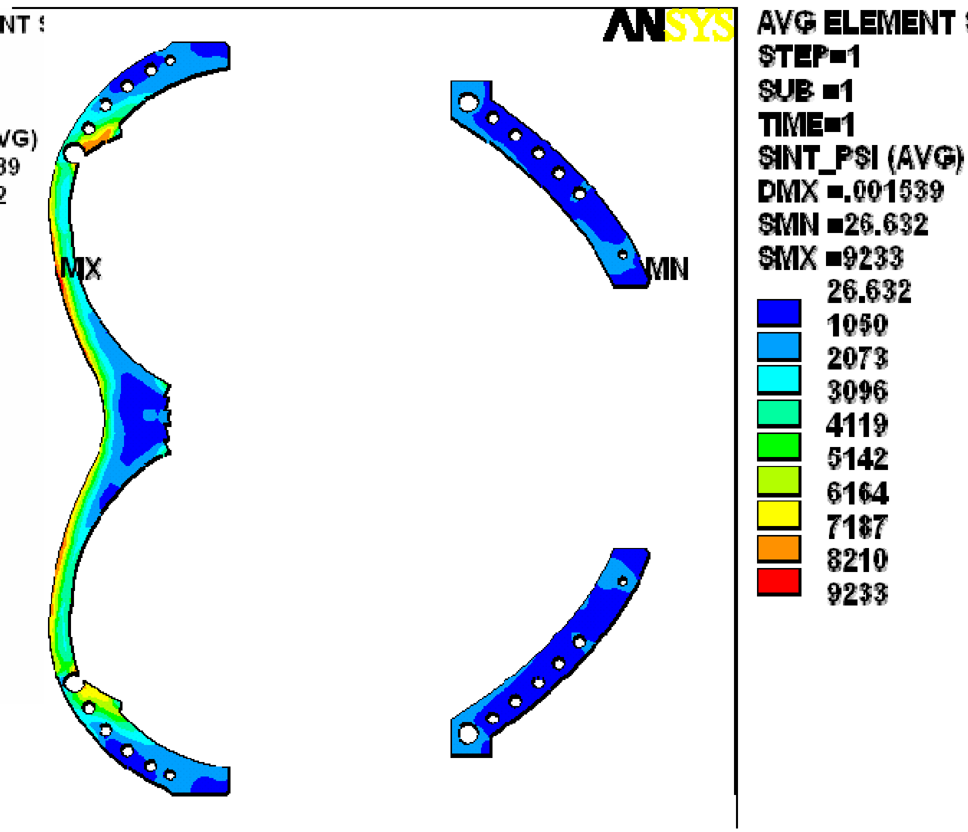


Currently Being Solved

AA Stress Intensity of Weld and shim (units are Psi)



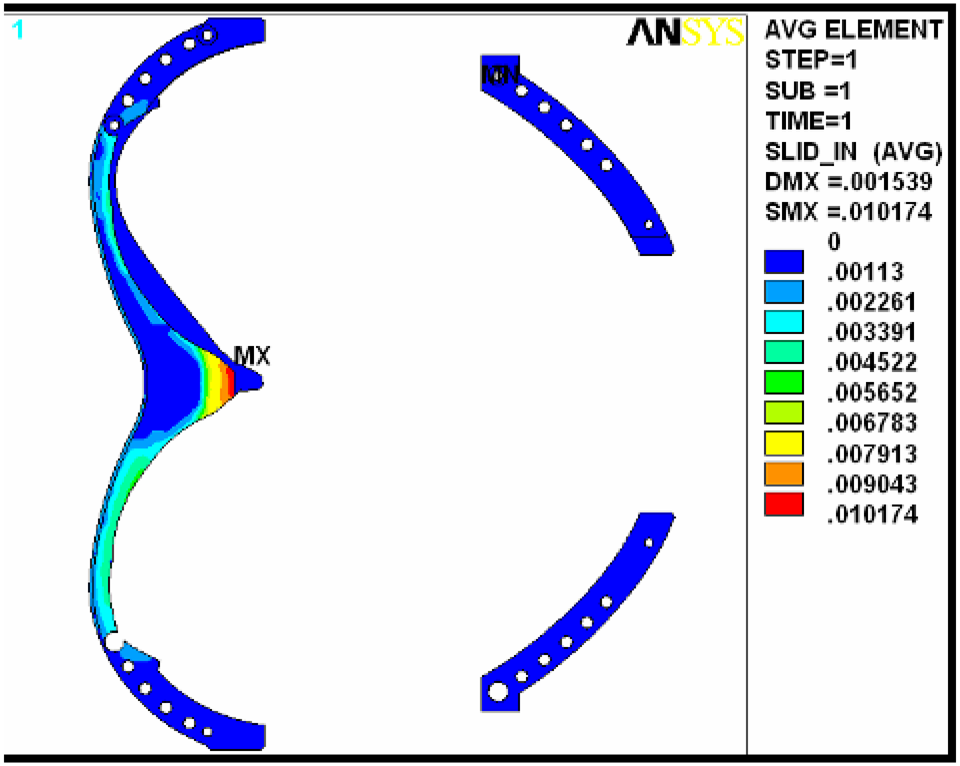
Complete shim

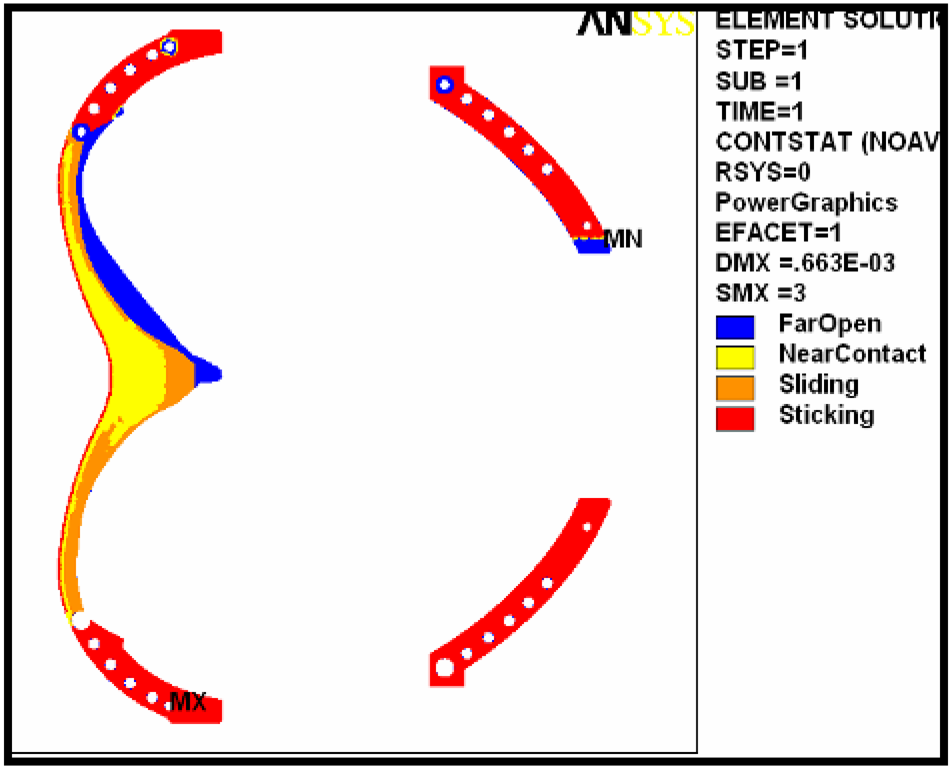


Removal of midline elements causing high stress intensity

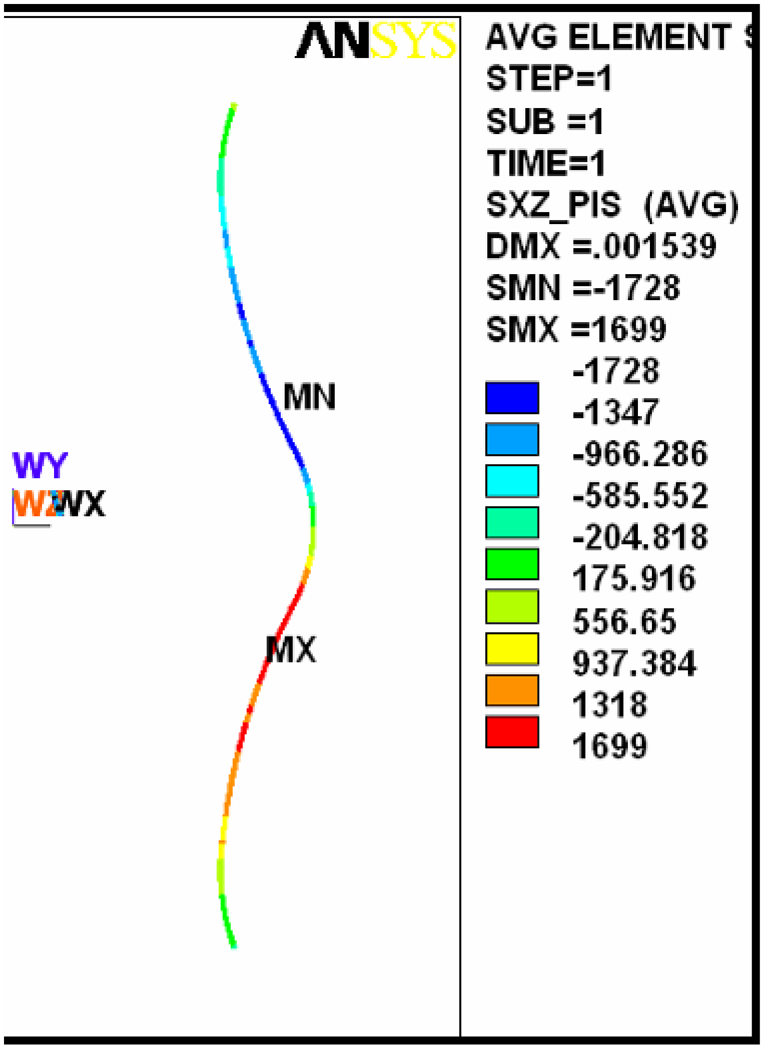
Peak Weld/shim stress is only 9 ksi!

AA Sliding and contact status (inches)

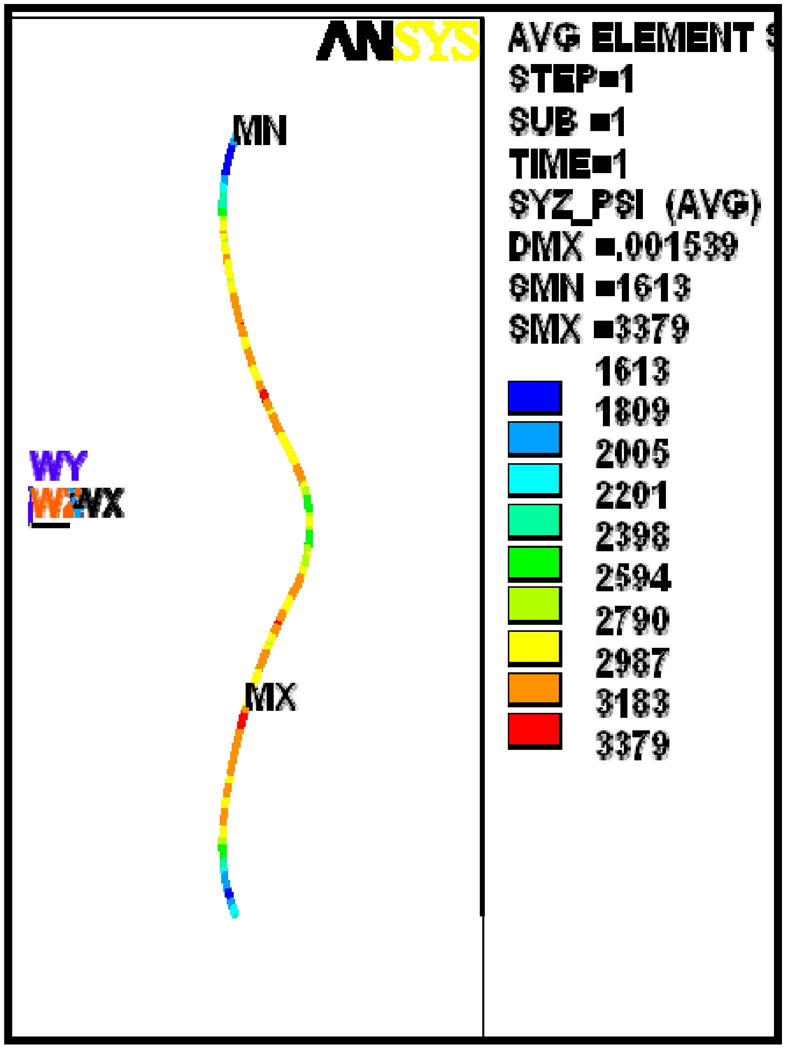




AA Weld Shear Stresses (psi)

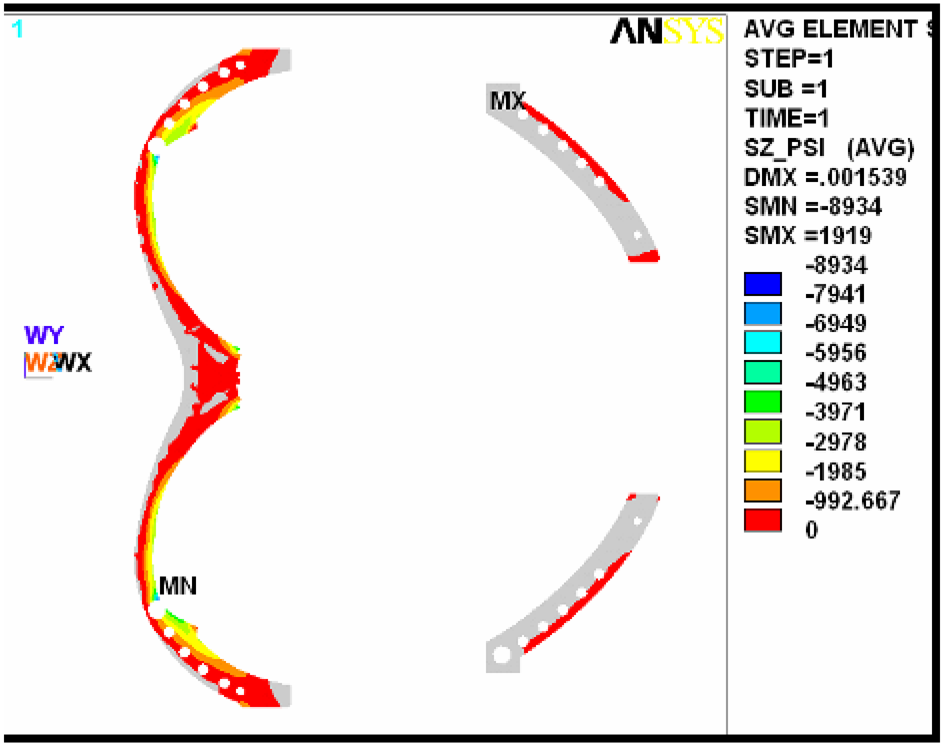


SXZ (horizontal shear)

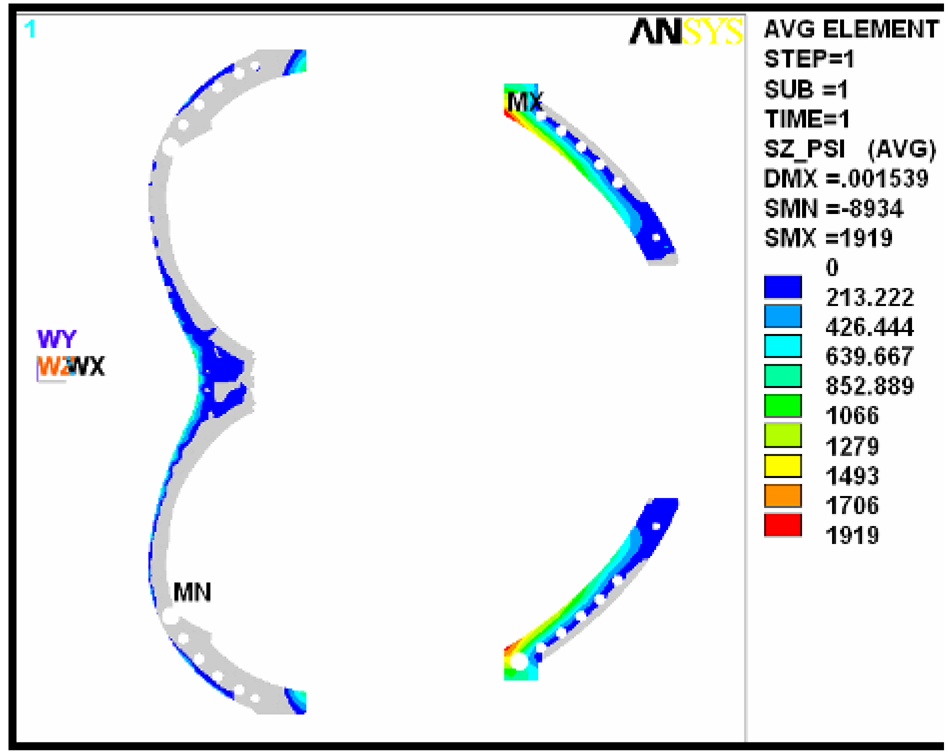


SYZ (vertical shear)

AA Normal Stress (Units are psi)



Grey = tension



Grey = compression

Next For welding

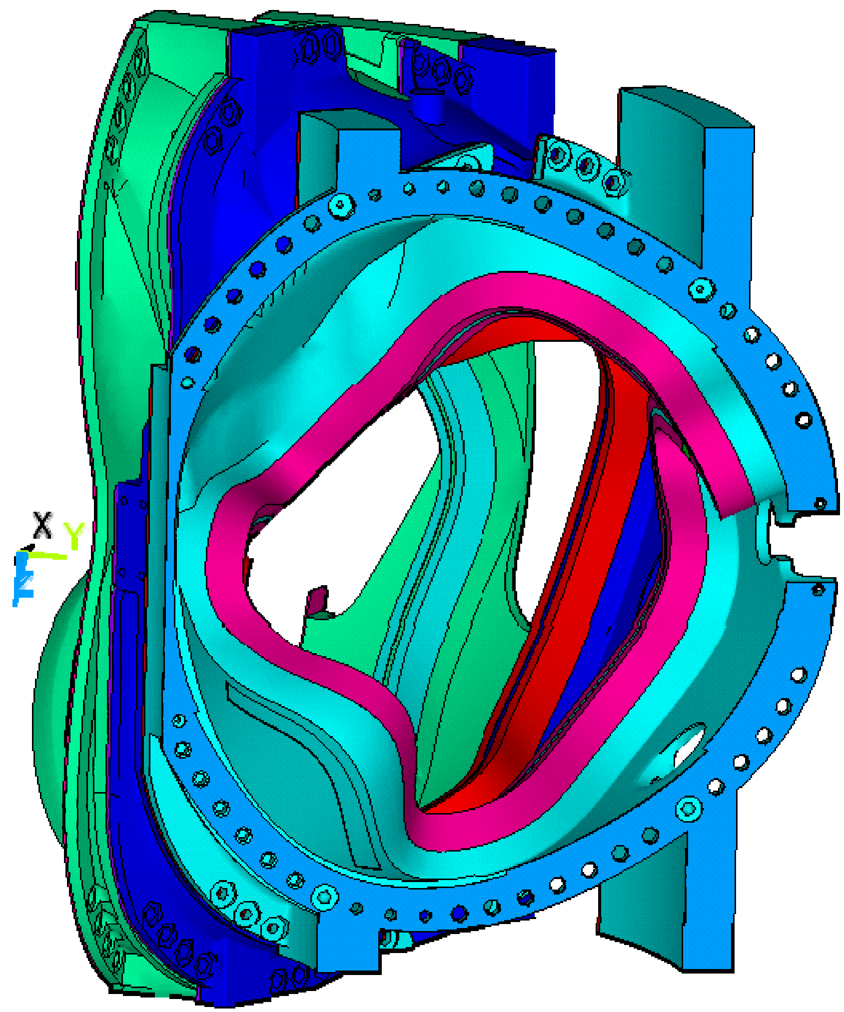
- Still need sub model of AB weld with correct weld geom. (need guidance from design team on shape) (type 2 in places?)
- Weld stresses on AA are low and there is little use for a sub model. **Weld AA is done**
- **Weld BC is done** (global, sub model and segmented).
- **Therefore the only remaining weld analysis is the sub model of AB which is marginally warranted based on stress levels and its unique weld geometry.**
- Fatigue Analysis is to be performed by EWI?

Subject Area # 2

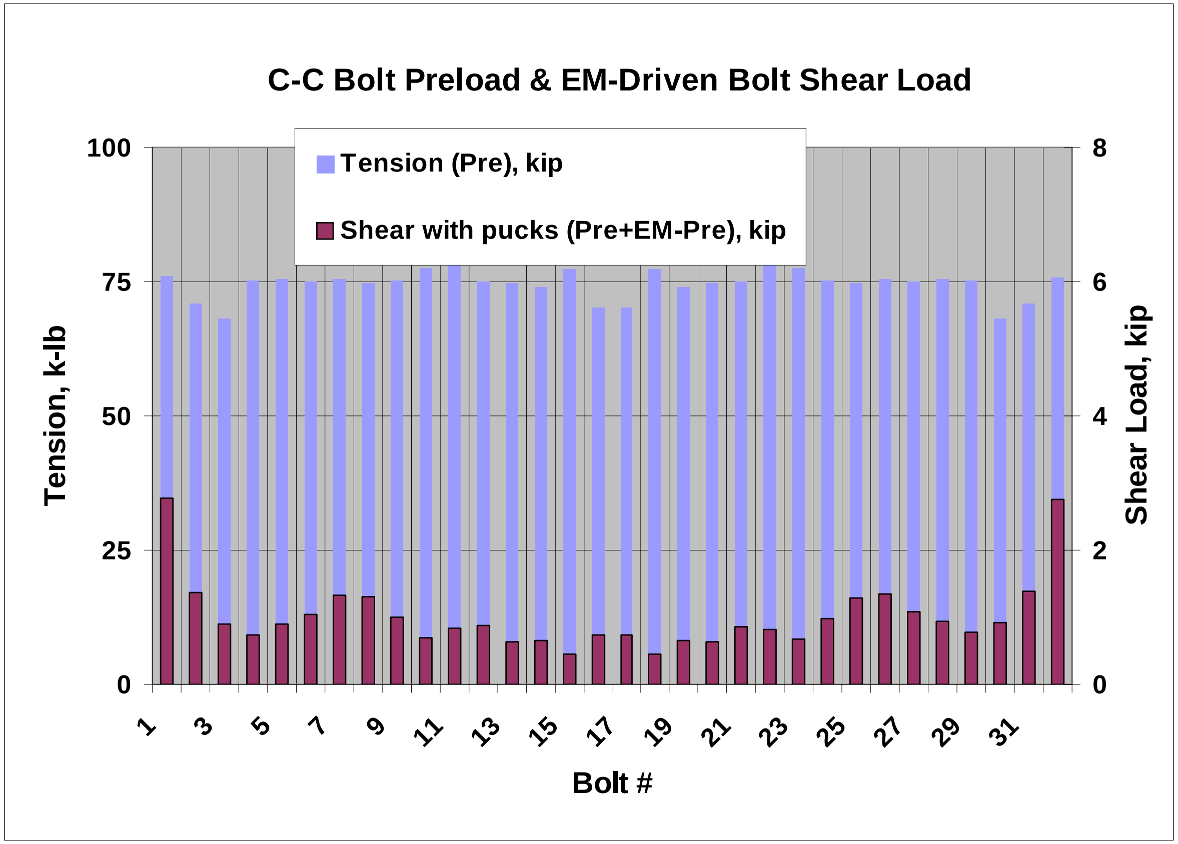
CC Connection

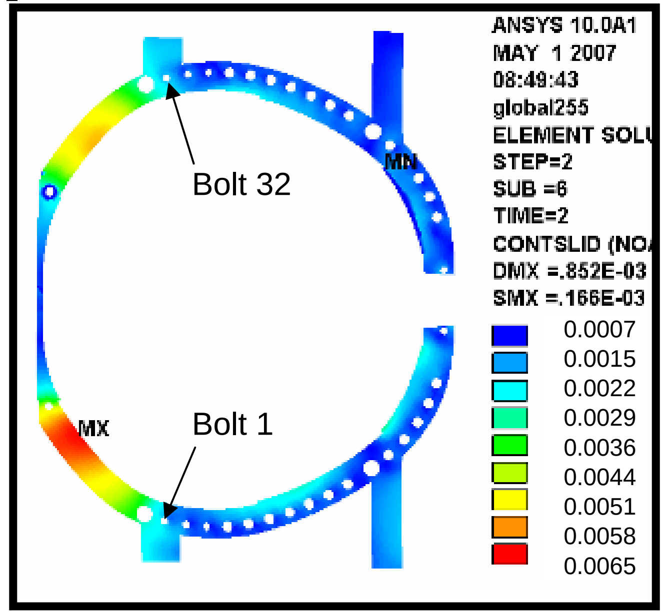
Options to restrain movement of inboard leg.

- Options include adding 3 to 6 bolts on the inner leg (model on right has 6 bolts added north and south of the midplane.



Friction = 0.4 everywhere on flange through alumina shims.

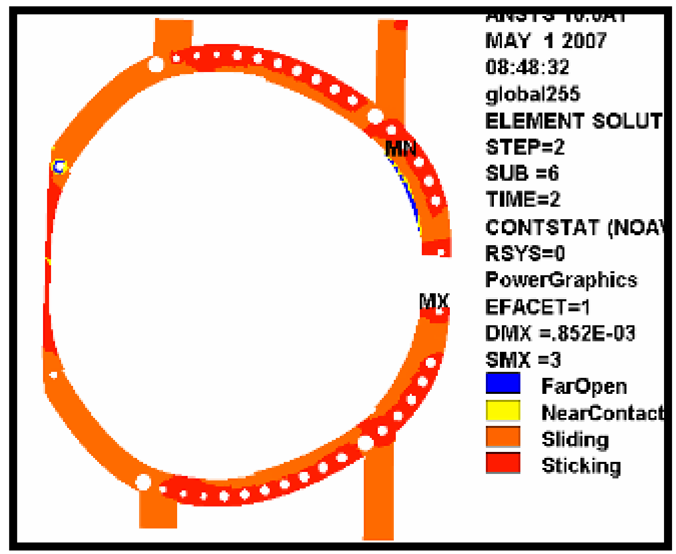




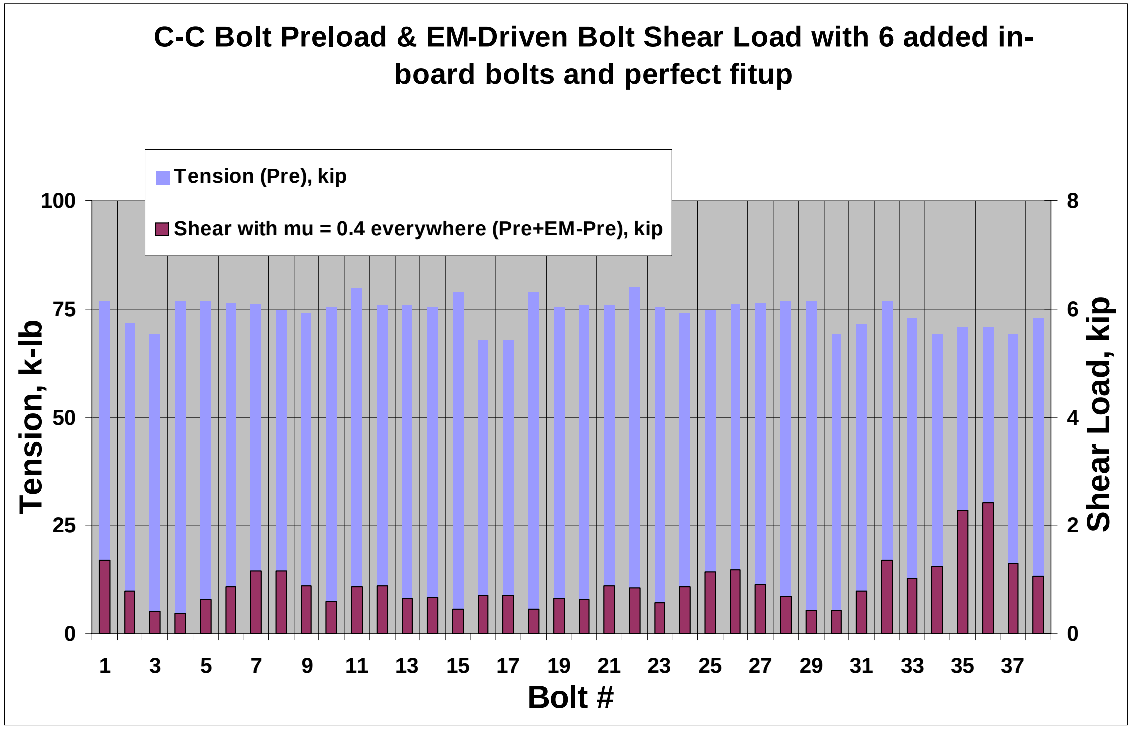
NO INBOARD BOLTS

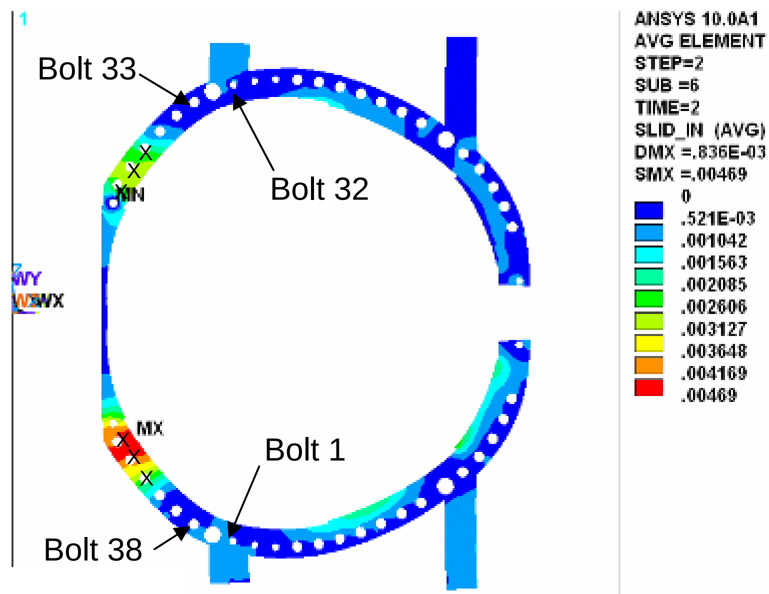
Peak Load is 2.8 kips

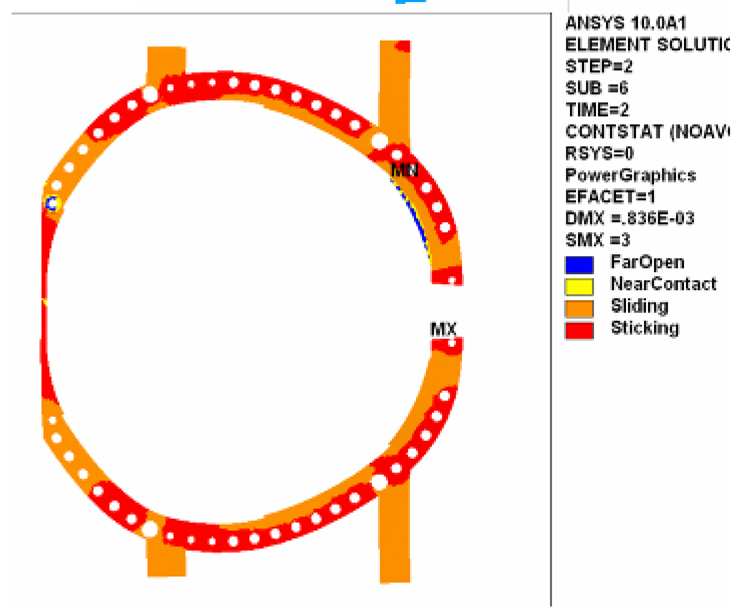
Sliding is 6.5 mils



Friction = <u>0.4 everywhere</u> on flange through alumina shims.







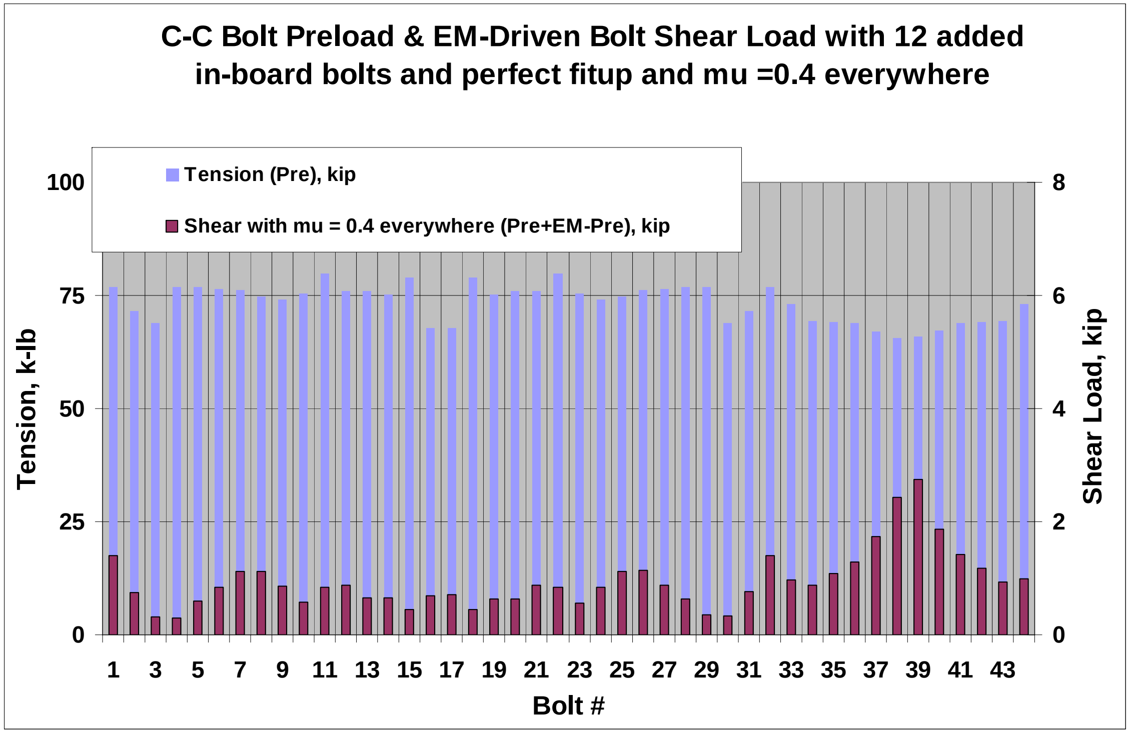
ADDED 6 Inboard Bolts

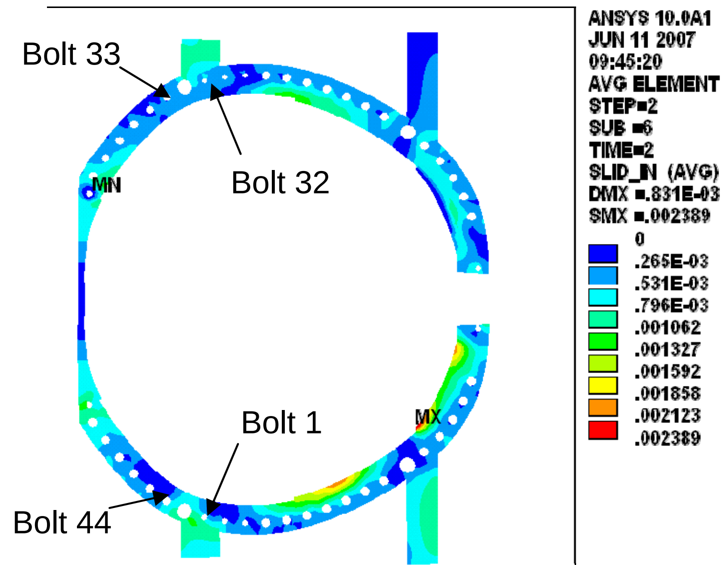
Innermost 6 bolts are shown but not used in the calculation (shown as x's in the sliding picture)

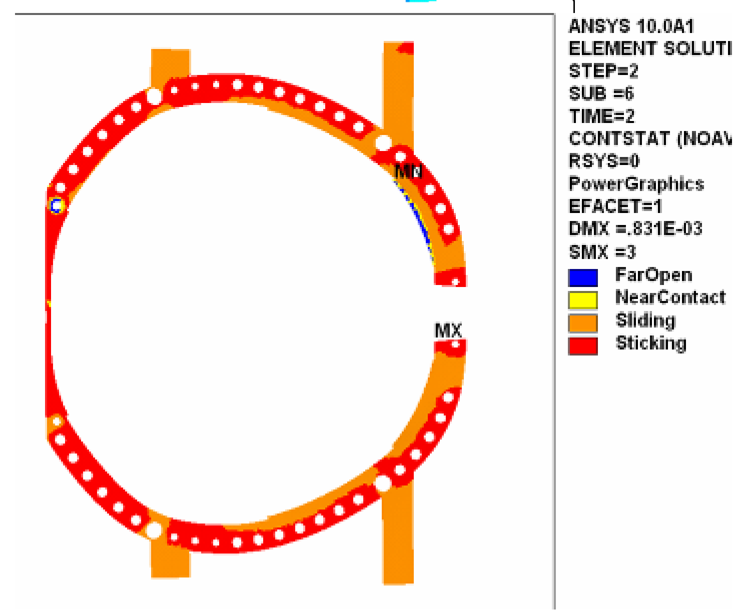
Inner most bolts see 2.4 Kips

Sliding is 4.7 mils

Friction = 0.4 everywhere on flange through alumina shims.





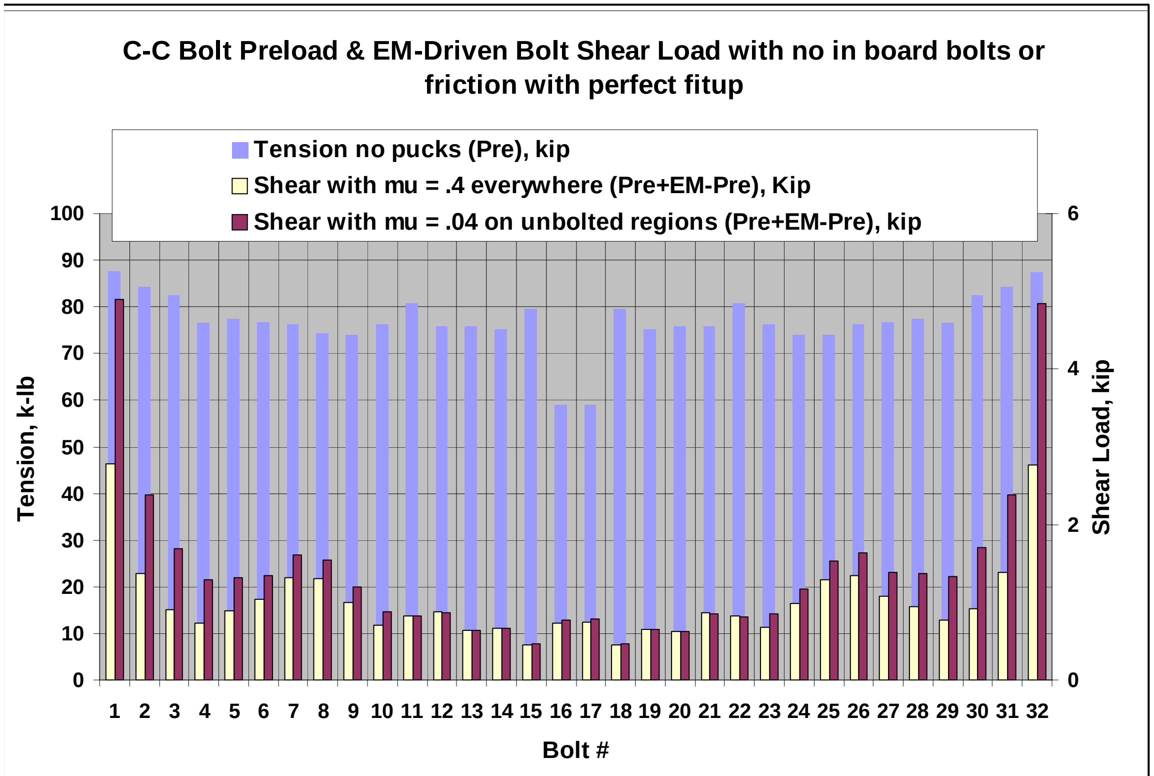


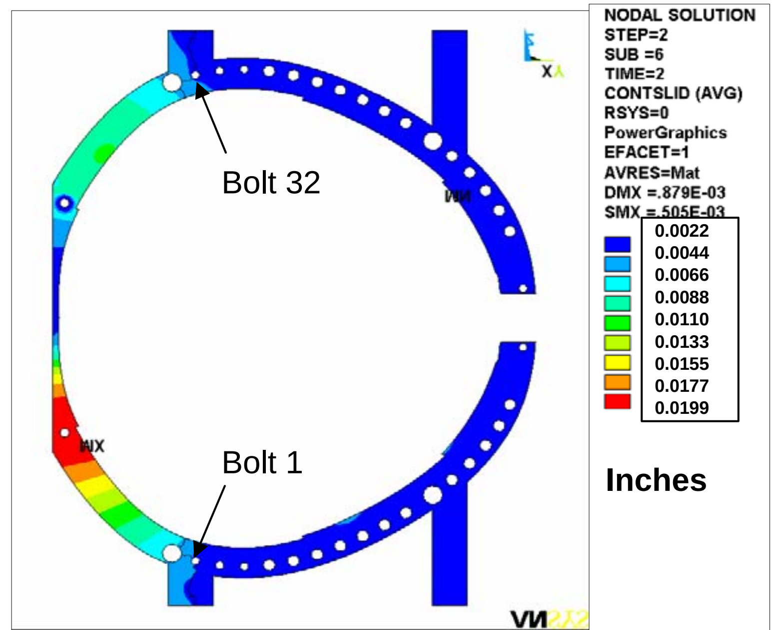
ADDED 12 Inboard Bolts

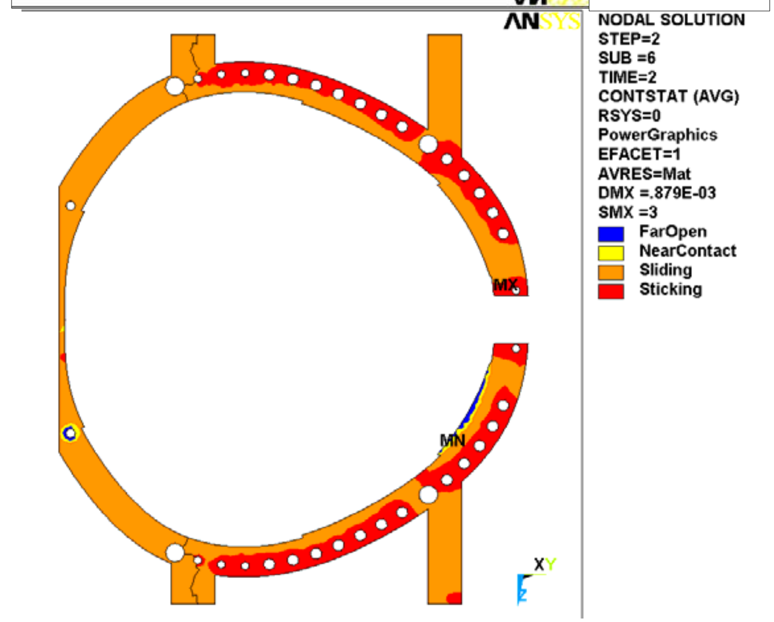
Inner most bolts see 2.7 Kips

Sliding is less than 1.3 mils

Friction = 0.04 on Inner-leg region, mu = 0.4 everywhere else







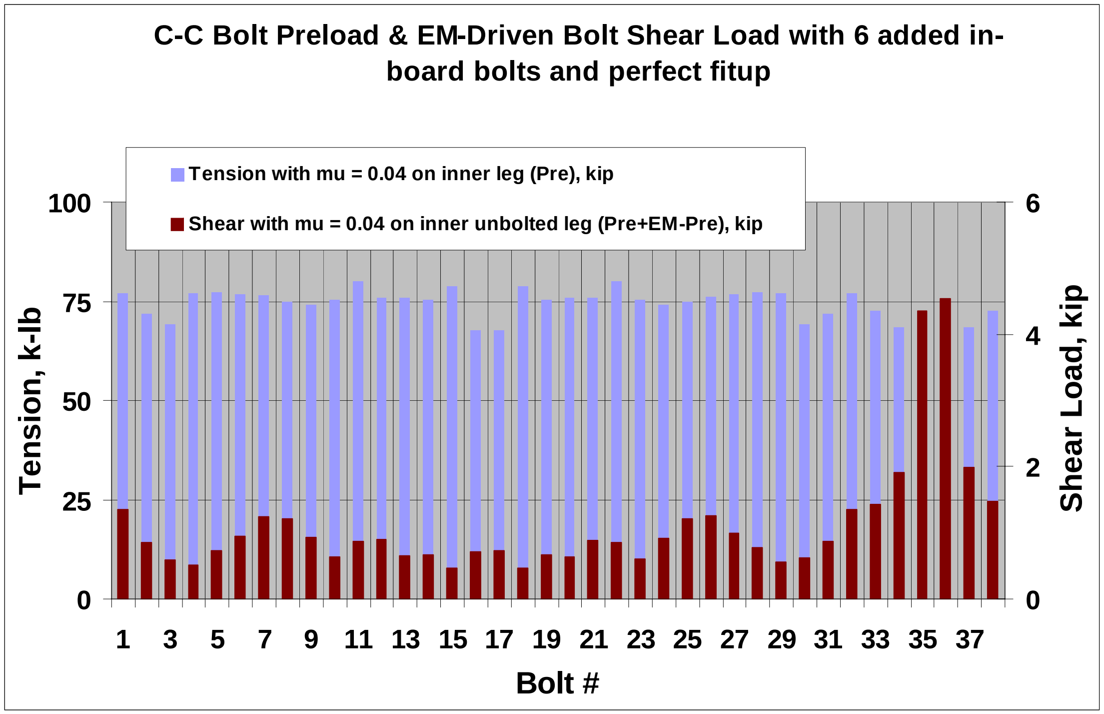
No Inboard Bolt Friction

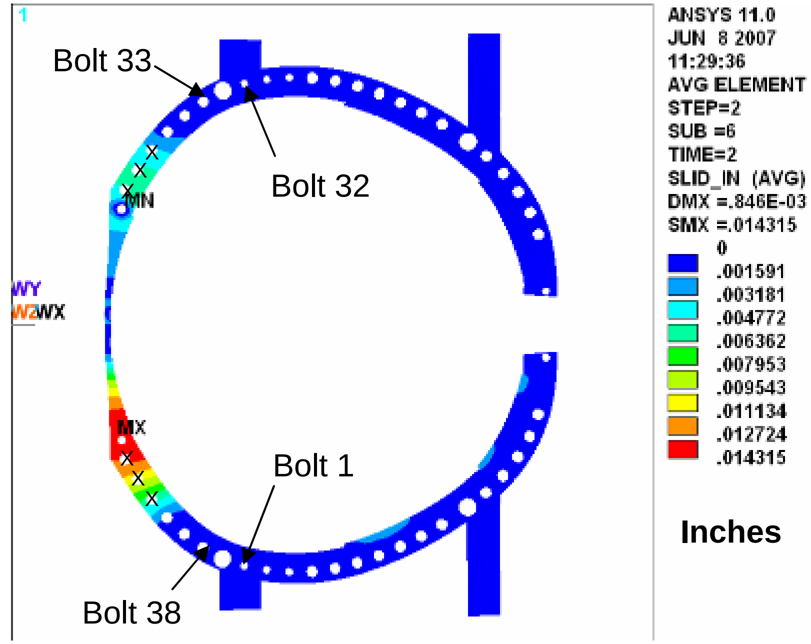
Frictionless In board leg

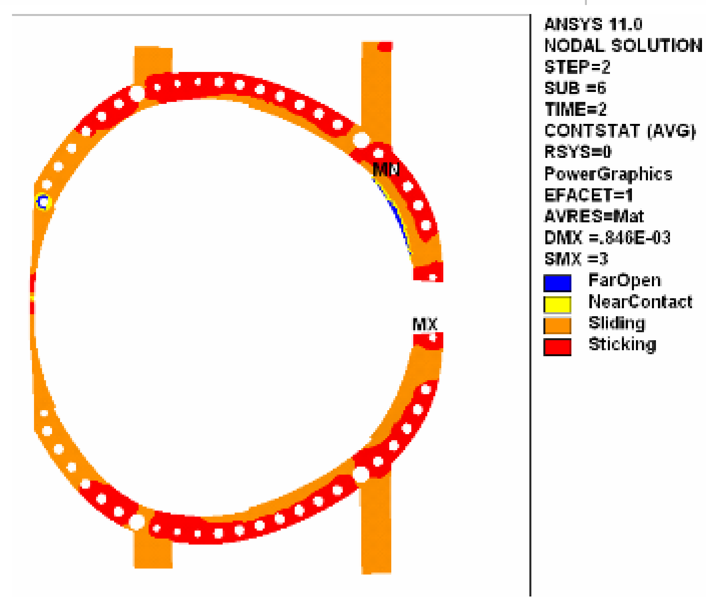
Peak Shear is 4.8 Kips

Sliding is 19 mils

Friction = <u>0.04</u> on Inner-leg region, mu = 0.4 everywhere else







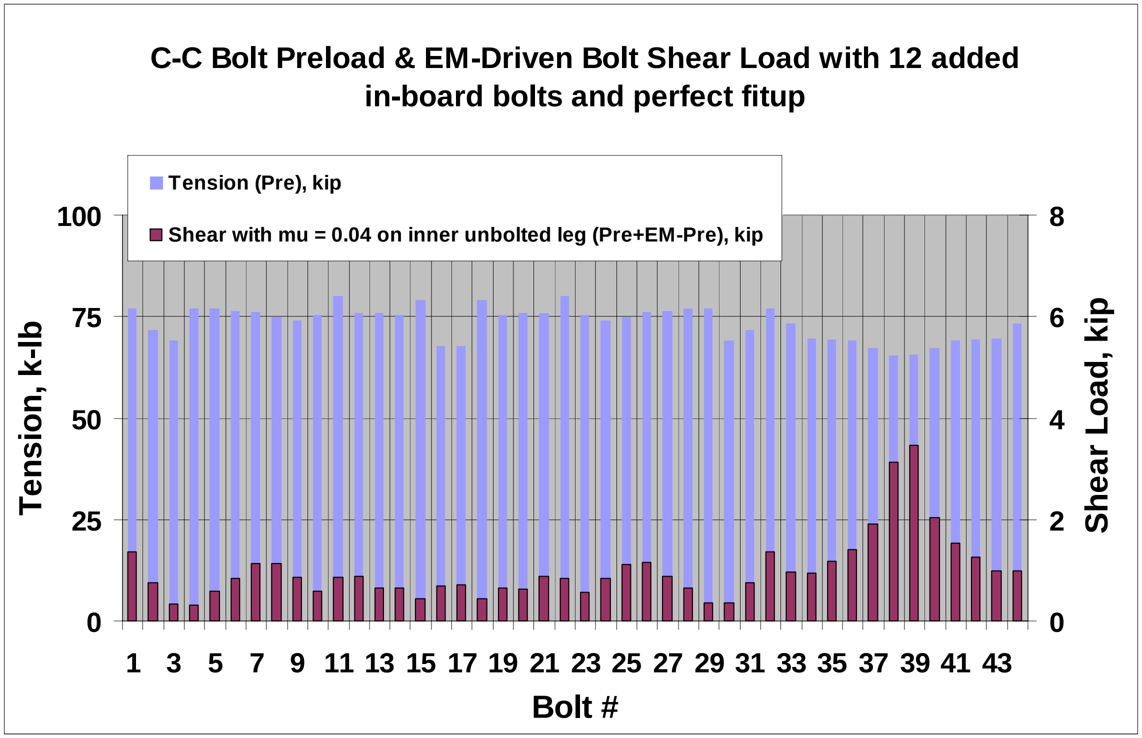
ADDED 6 Inboard Bolts

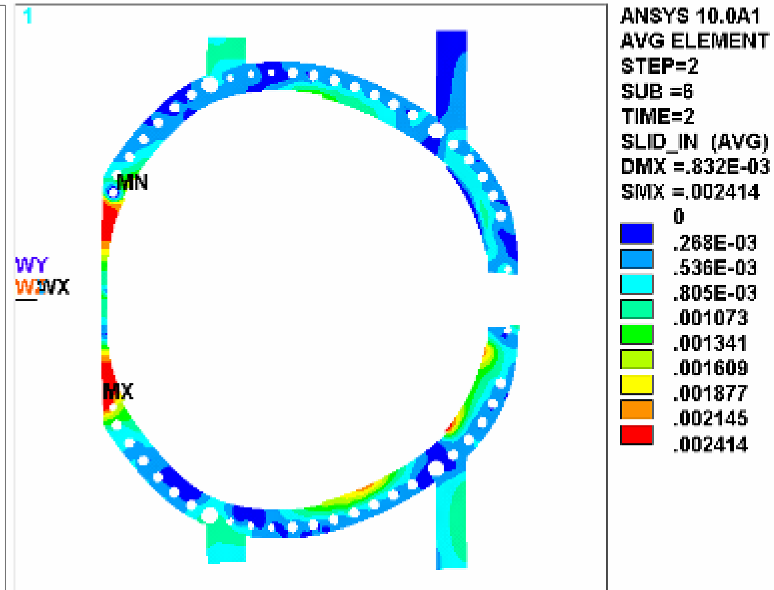
Frictionless In board leg

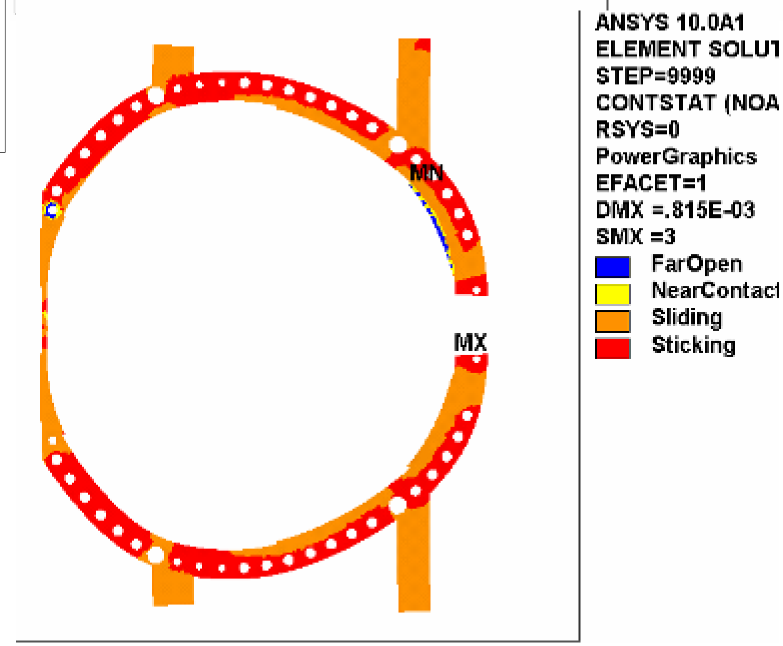
Peak Shear is 4.8 Kips

Sliding is 14 mils

Friction = 0.04 on Inner-leg region, mu = 0.4 everywhere else





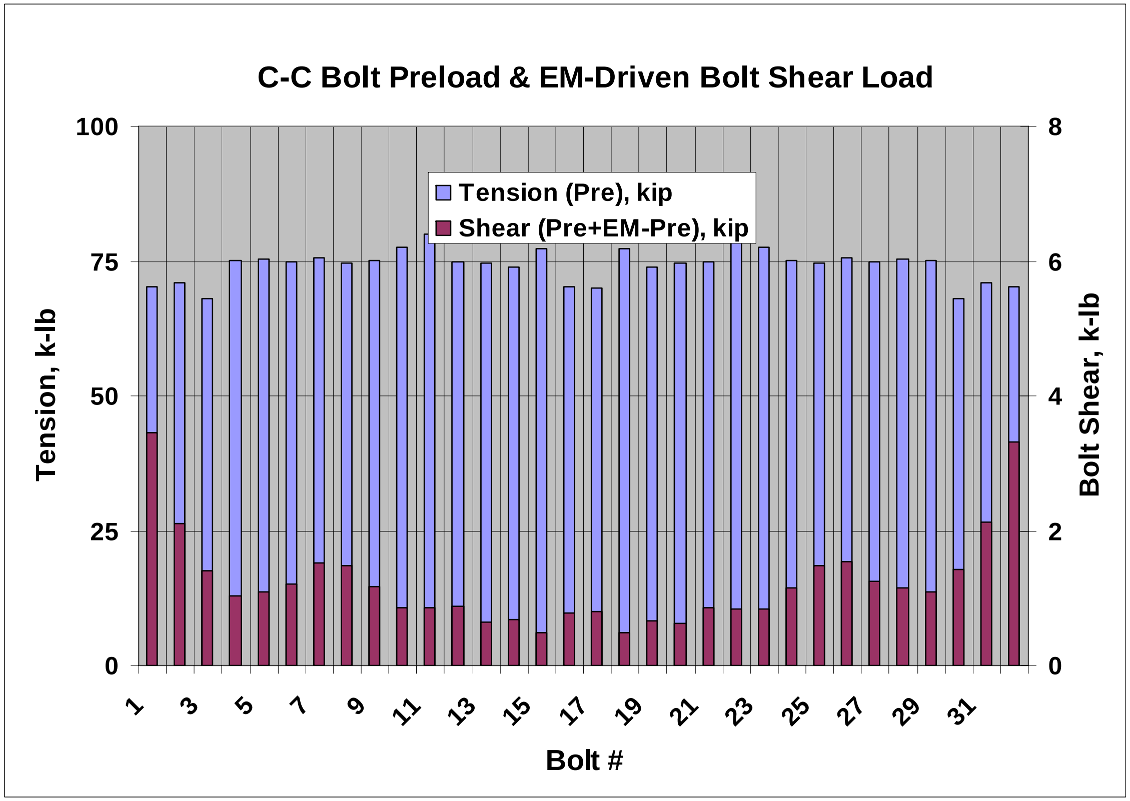


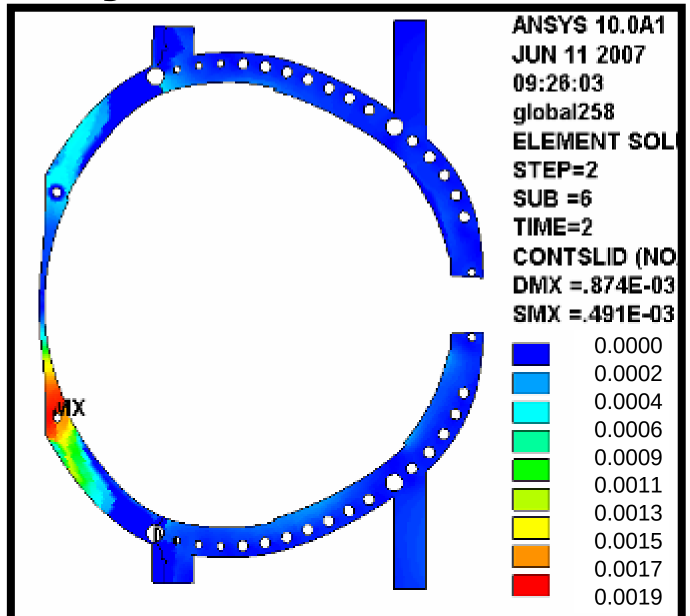
ADDED 12 Inboard Bolts

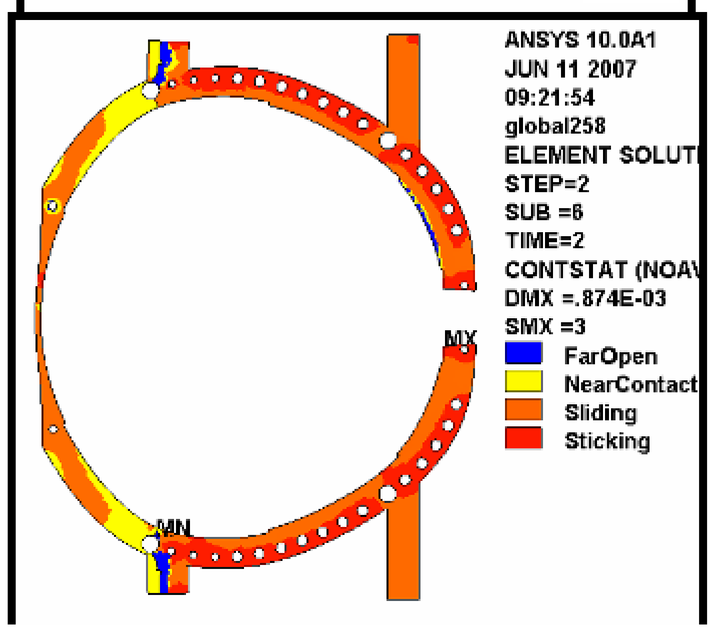
Inner most bolts see 3.4 Kips

Sliding is less than 2.4 mils

0.005 " gap on inboard leg Friction = 0.04 on Inner-leg region, mu = 0.4 everywhere else







No Added Inboard Bolts
Inner most bolts see 3.3 Kips
Sliding is more than 19 mils

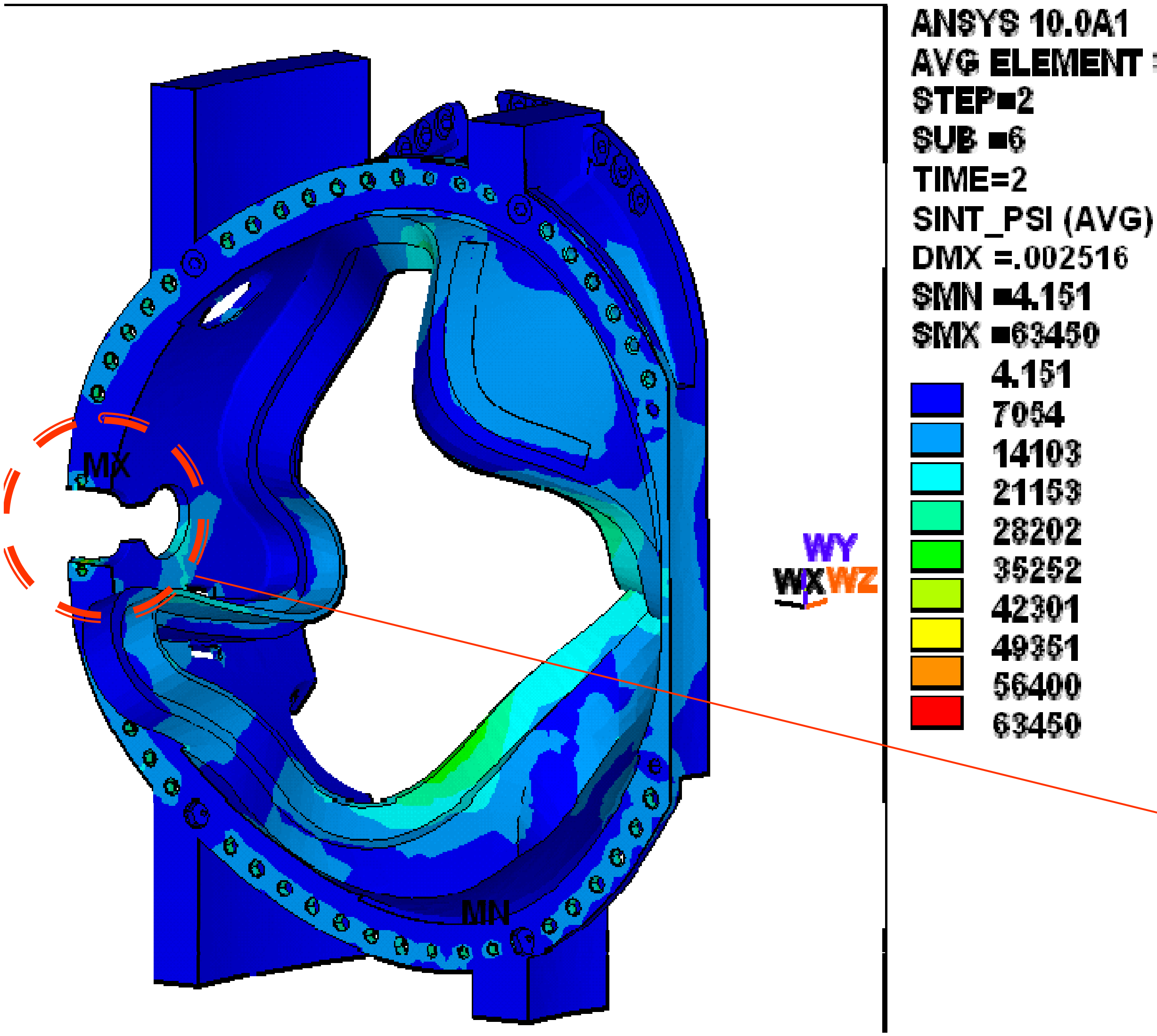
Max sliding and bolt shear table

Inboard Friction	# of inboard bolts	Max sliding distance (in)	Max Shear Force (kips)
0.4	0	0.0065	2.8
0.4	6	0.0047	2.4
0.4	12	0.0011	2.7
0.04	0	0.0199	4.9
0.04	6	0.0143	4.5
0.04	12	0.0024	3.5
Imperfect Fit-up gap of .005" on unbolted region	0	0.0193*	3.3

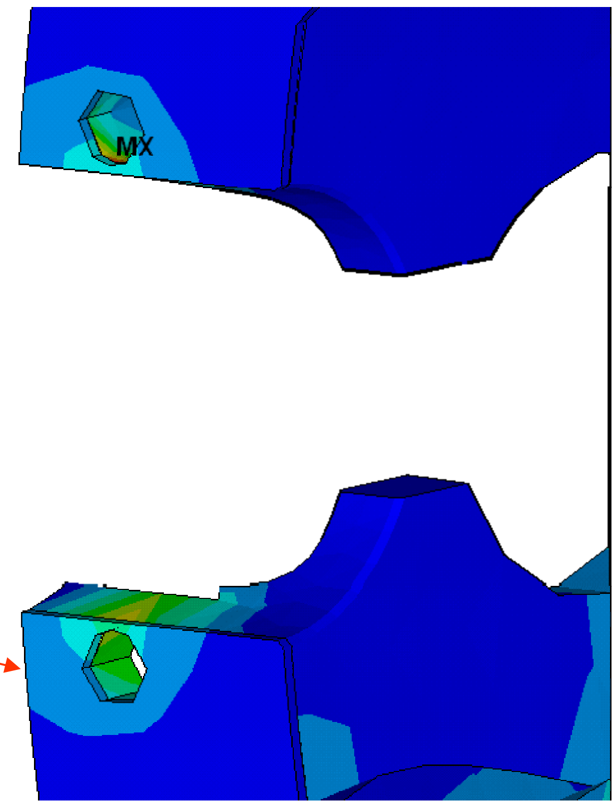
*sliding occurs after gap has closed

*Number of bolts is the total number added: 12 bolts means 6 bolts added above and below the mid-plane.

Stress Intensity of flanges around bolts

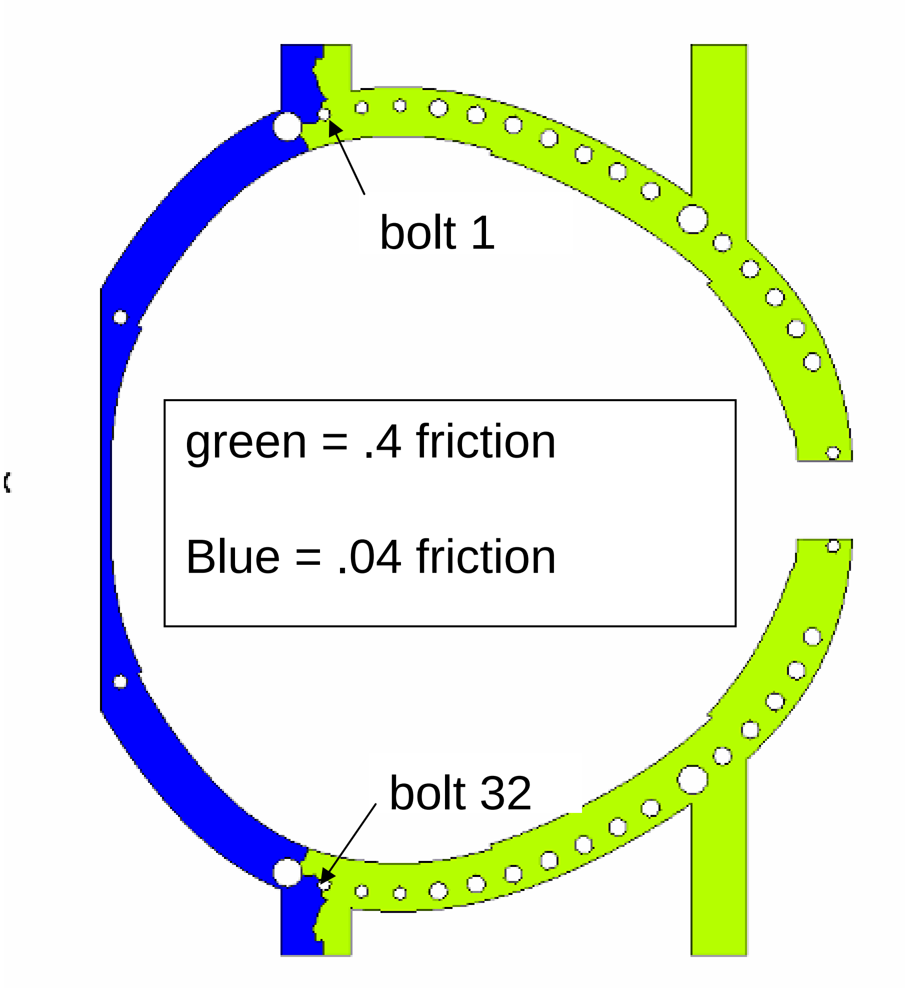


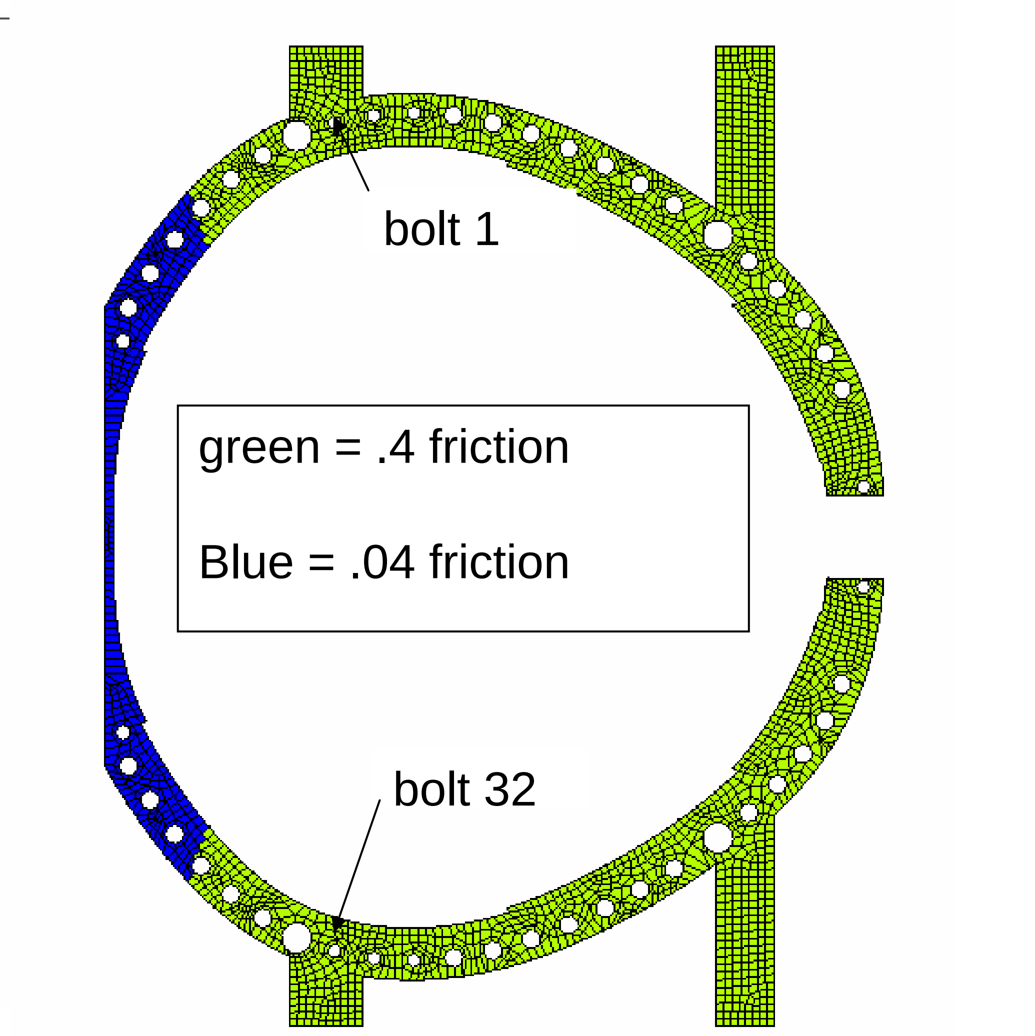
This case has mu = .4 and 12 added inboard bolts



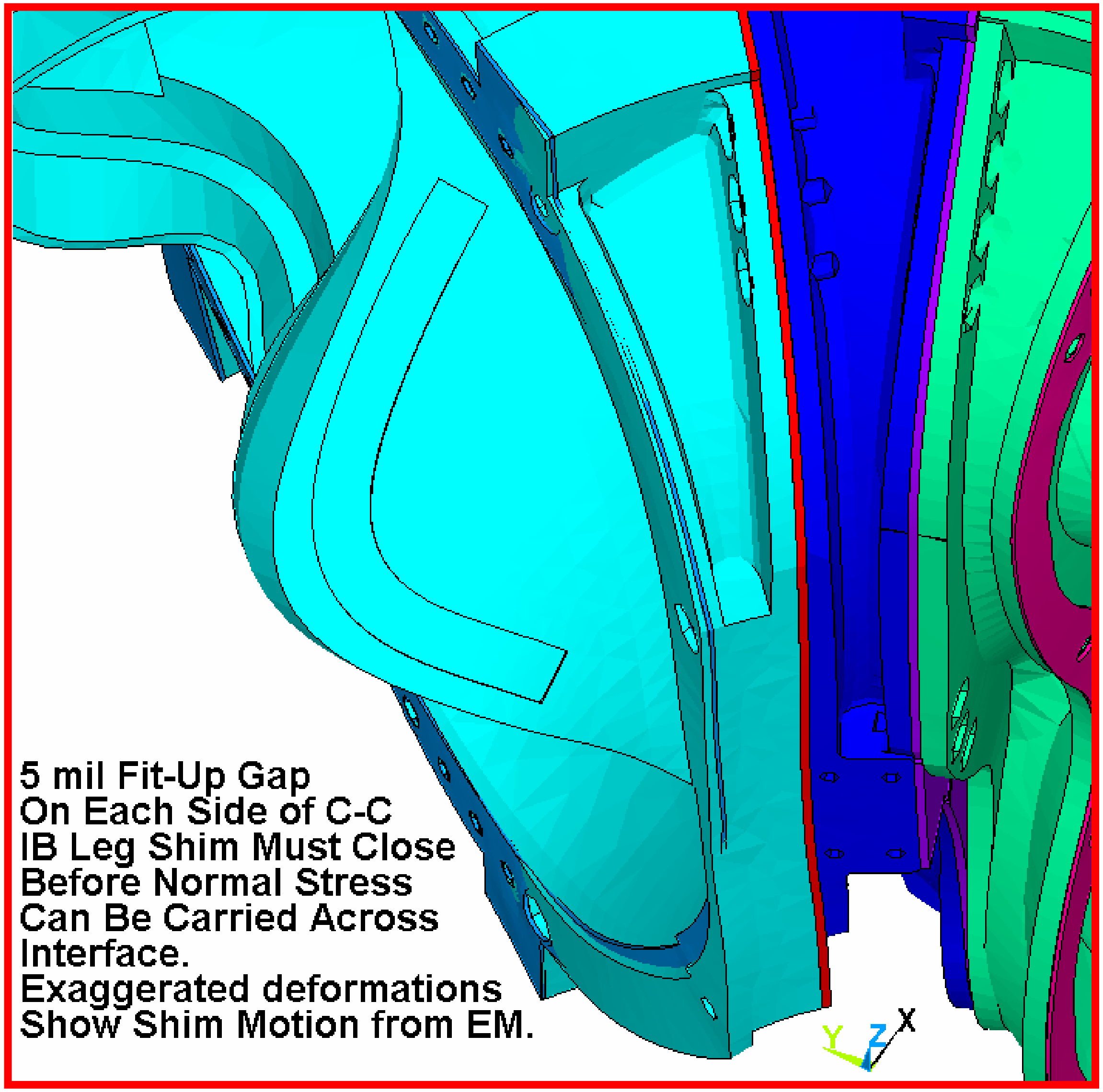
Tear out type stresses (peak 64 ksi, average approx 48 ksi) on this flange are a bit bothersome, may want to consider leaving these two bolts out.

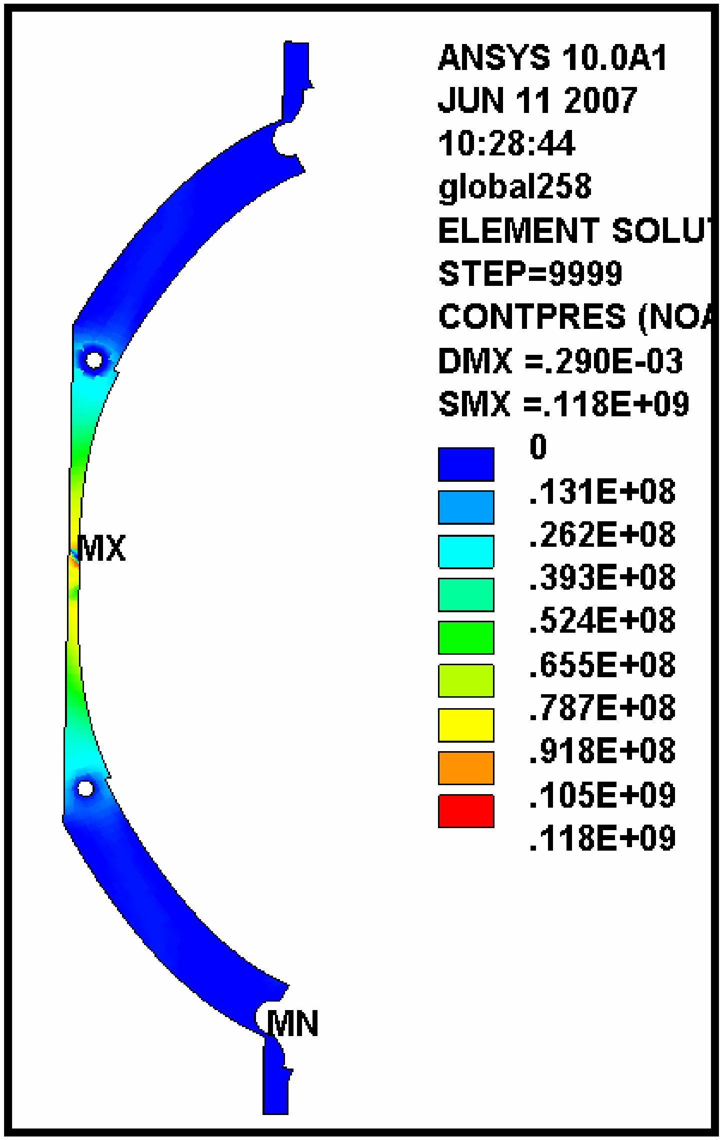
Contact Sliding regions



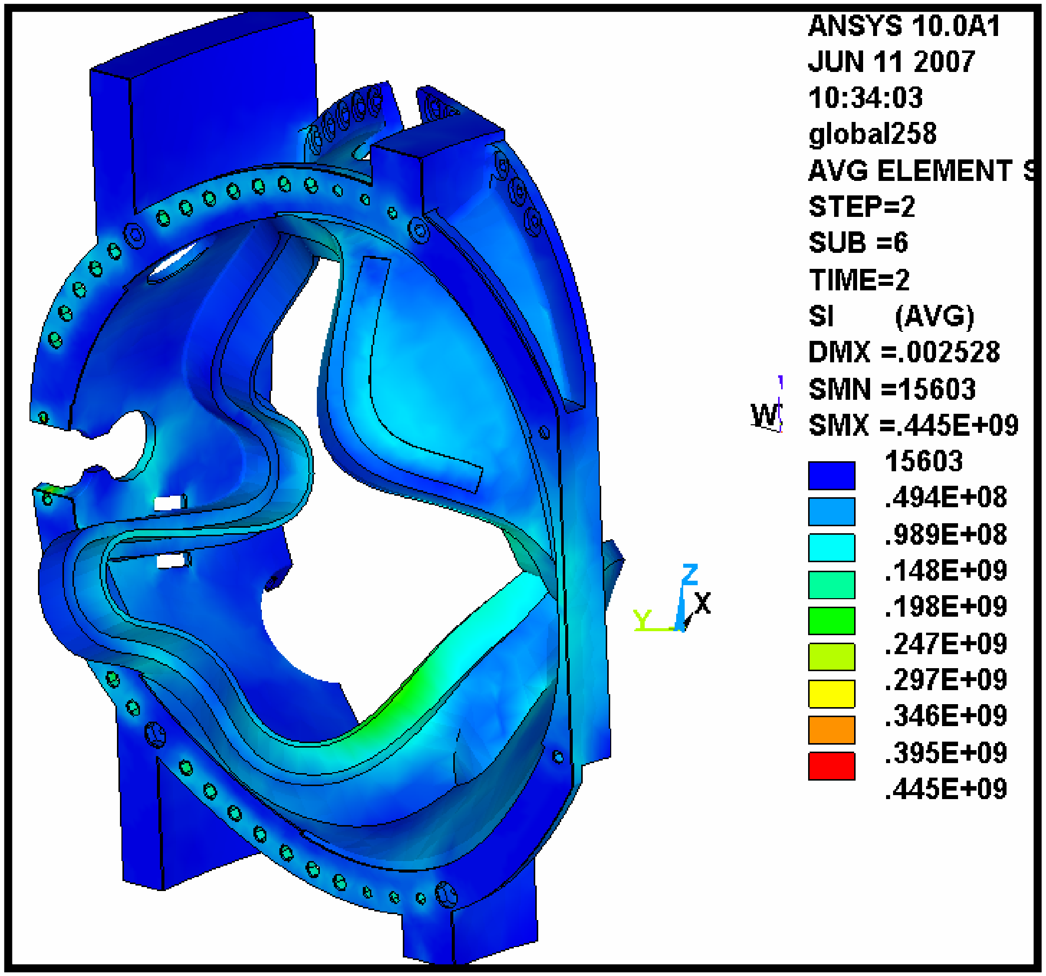


Slides from imperfect fit-up run

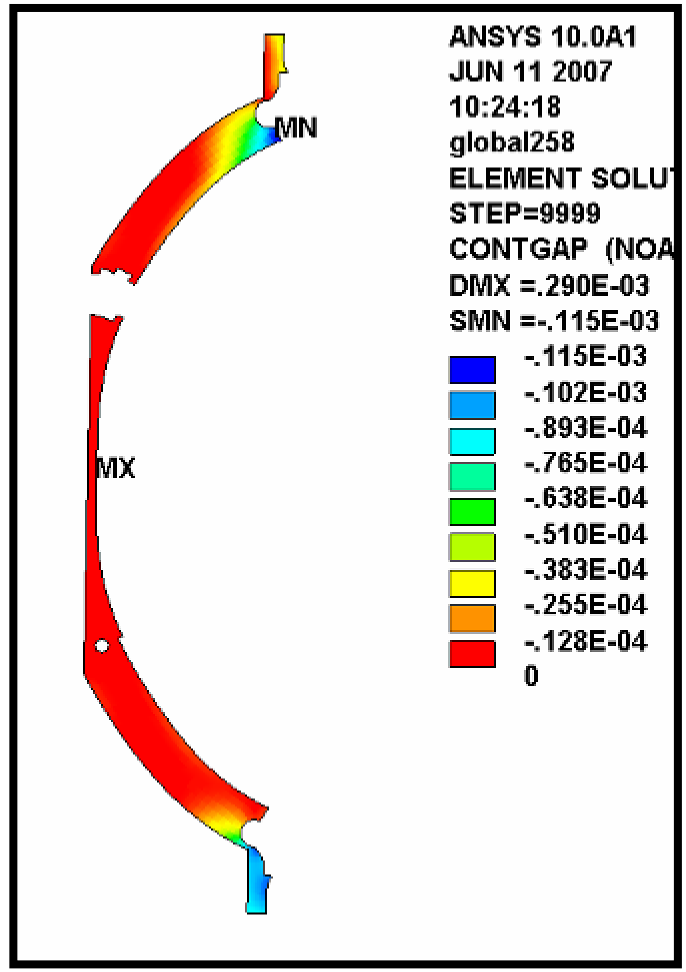




Slides from imperfect fit-up run



Stress intensity Plot (Pa)



Gap Plot (Pa)

CC Analysis Outcome

- **If 12 inner bolts are added all shear and sliding problems on CC are eliminated**. (Using less bolts away from the peak sliding area / innermost inboard region has a high probability of also working.)
- ***Hopefully, the inner most bolt can be reached,* in which case, the number of added bolts can once again be dropped from 12 to 6 with the inner 6 most** .
- **bolts being the ones utilized.**
- 12 bolts have been added to the drawings as a means to provide maximum flexibility before access can be determined.
- Once access is determined, model with the correct number of bolts and placement if needed.
- Provide strain gages in the inner bolts to monitor compression /preload

Tying all the Analysis together.

- To date, we have examined bolt stresses (using mu = .4 everywhere **with added in board bolts)** and weld stresses (by locking the outboard leg) in two separate analysis packages/runs.
- A final model of AA, AB and BC with both welds and bolts may be warranted to determine the most complete loading picture on the bolts and flanges.
- Currently, without the welds, the global models has approximate shear loads on the end bolts of 1.8 kips on the AA flange, 1.6 Kips on the AB flange and 2.1 Kips on the BC flange. (note: the loading on the now removed in-board bolts was higher) {See Myatt Analysis report}
- It is possible that a lower coefficient of friction value may be allowed on the outer bolts now that the inboard is welded.