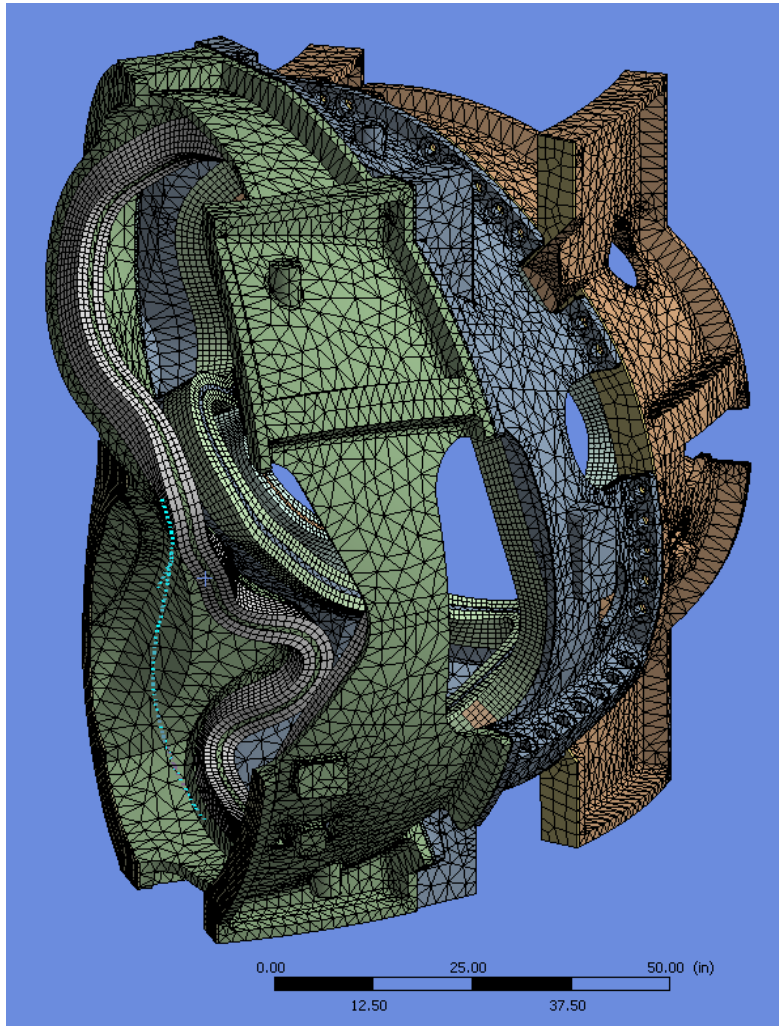


**Modular Coil Analysis (with welds)  
and the CC bolt Connection schemes**

6-18-07

# New Global Model with weld on BC joint



## Changes:

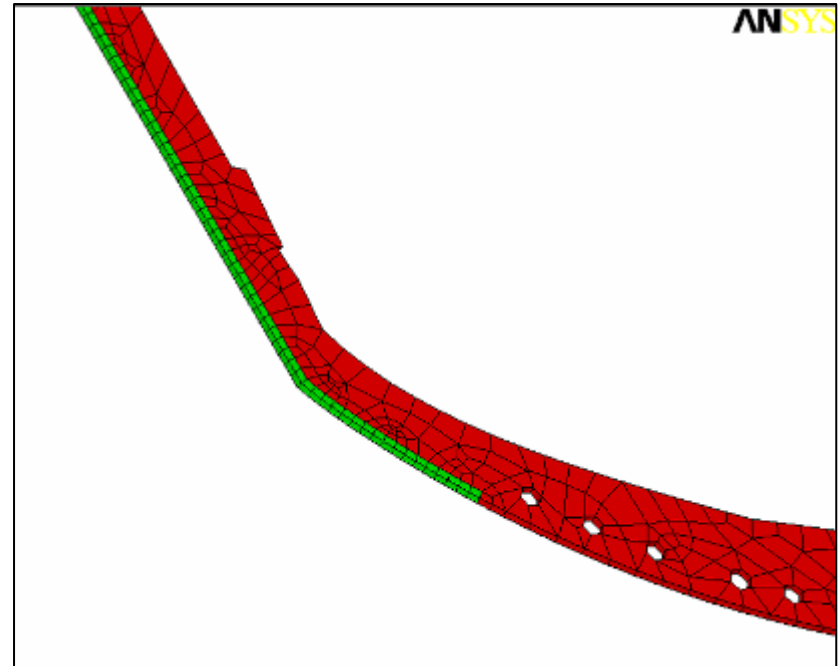
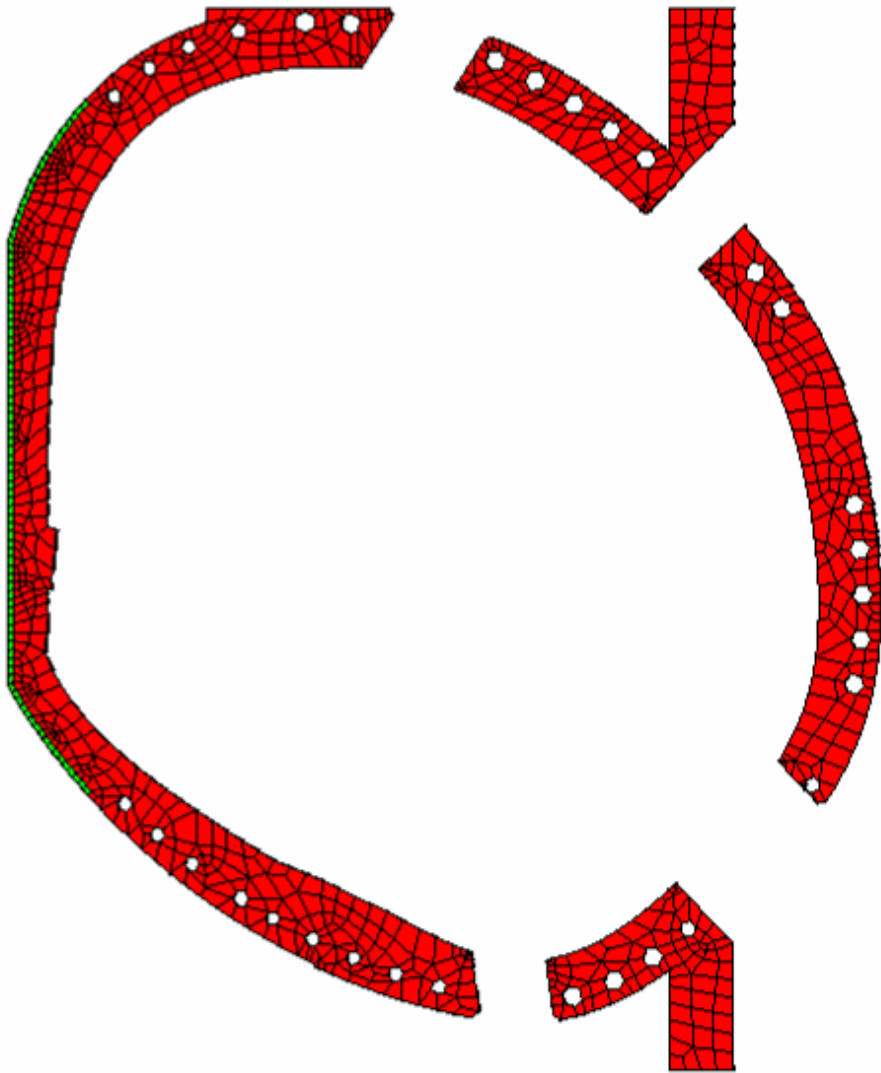
Bolt holes and bolts taken out of all flanges except the one of interest (BC). Allows us to add in bolts latter.

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

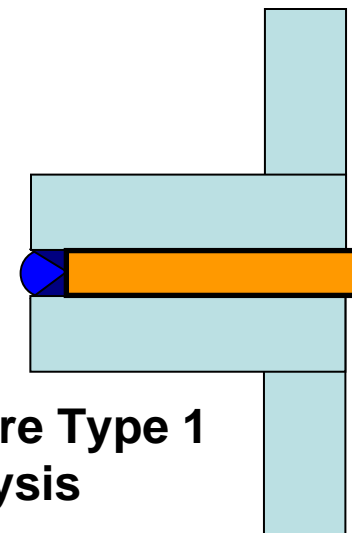
Method will be to lock up the outboard side with bonded contact but have the inboard side run frictionless with the weld taking the shear and tension from the flanges..

**Material Props of weld match that of shim and castings**

# BC Flange (coarse global model)

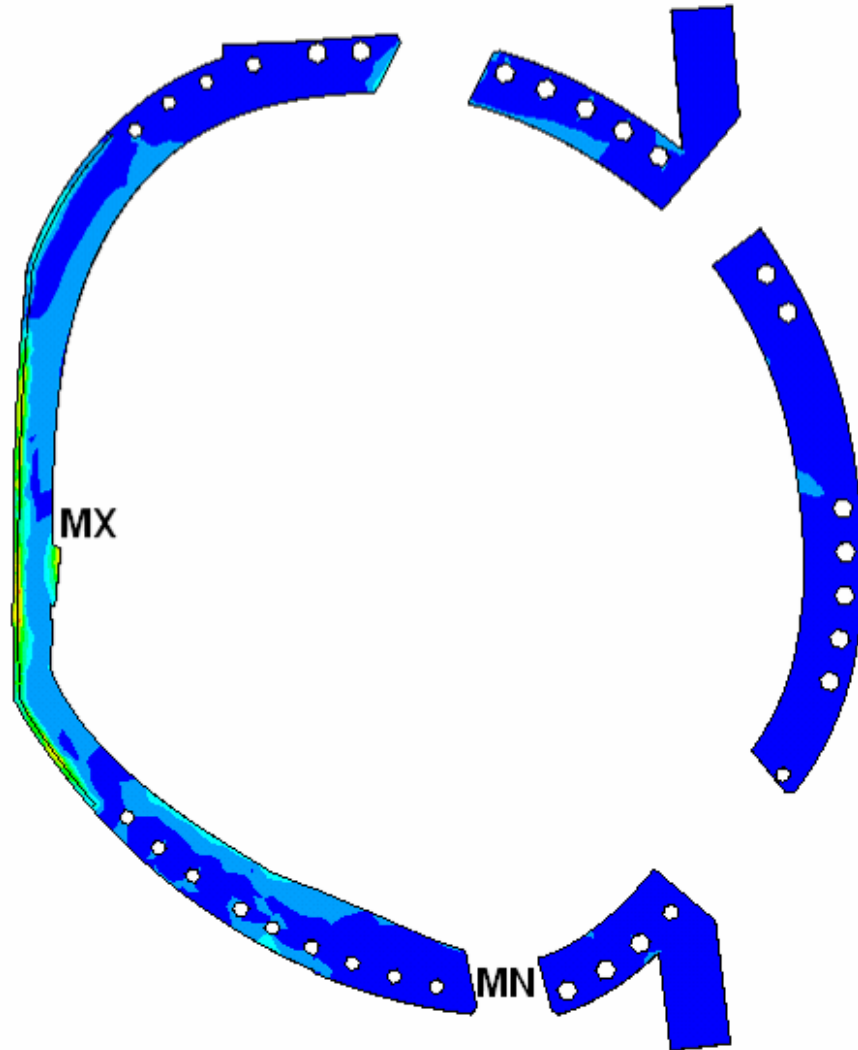


Weld is green elements are 20 node bricks.

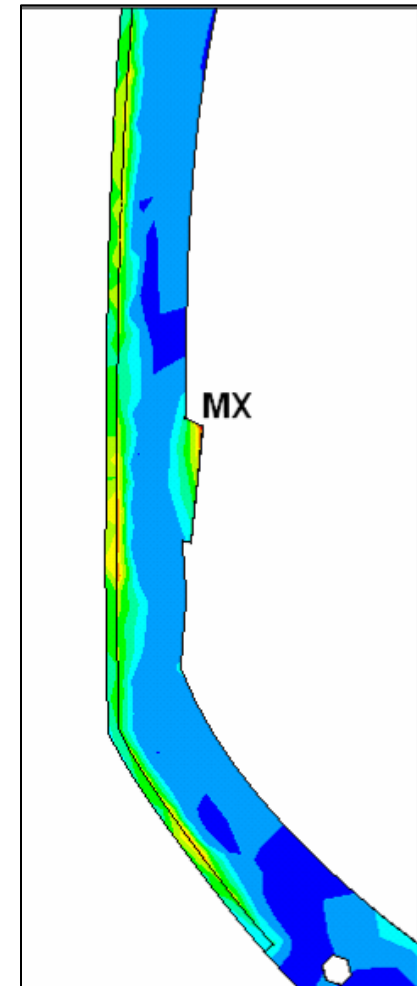


All welds are Type 1 in the analysis

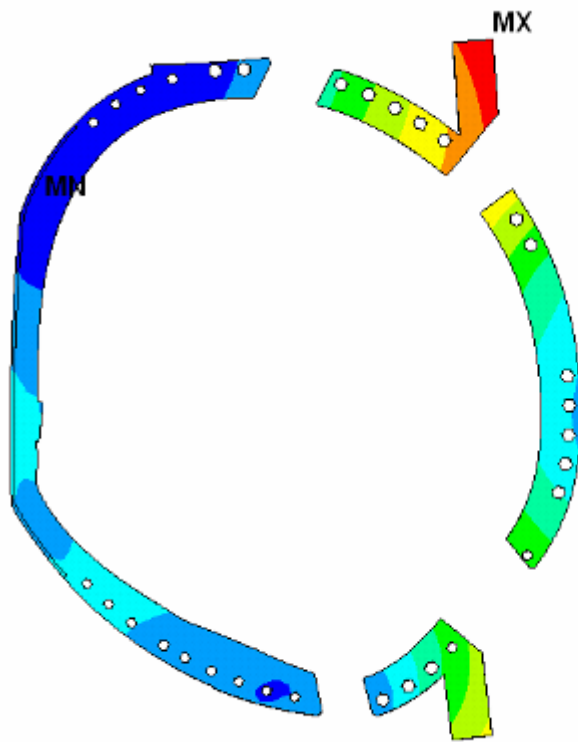
# Stress intensity (units are Pa)



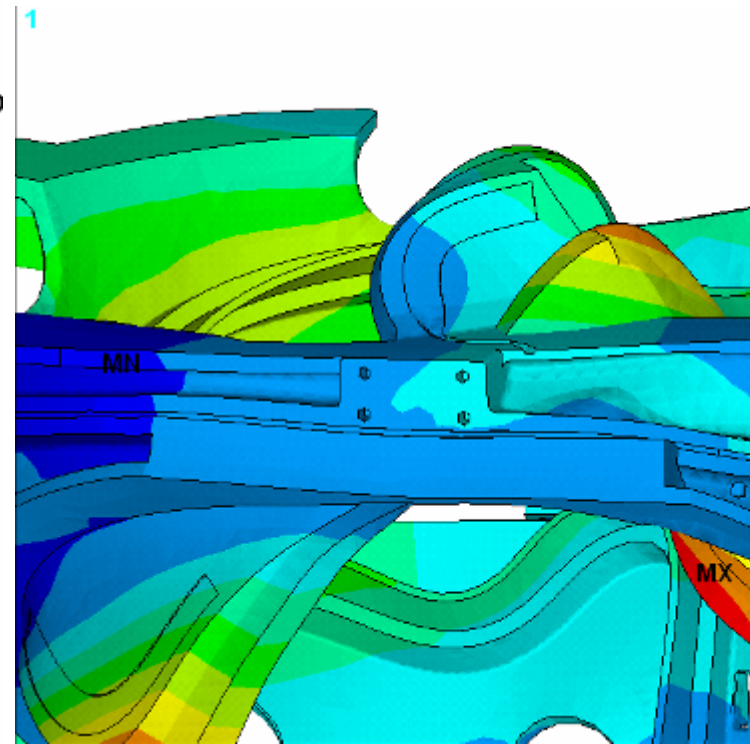
ANSYS 11.0  
MAY 23 2007  
18:15:26  
NODAL SOLUTION  
STEP=1  
SUB =1  
TIME=1  
SINT (AVG)  
PowerGraphics  
EFACET=1  
AVRES=Mat  
DMX =.001075  
SMN =170107  
SMX =.247E+09



# Deformations (global) (Units are meters)

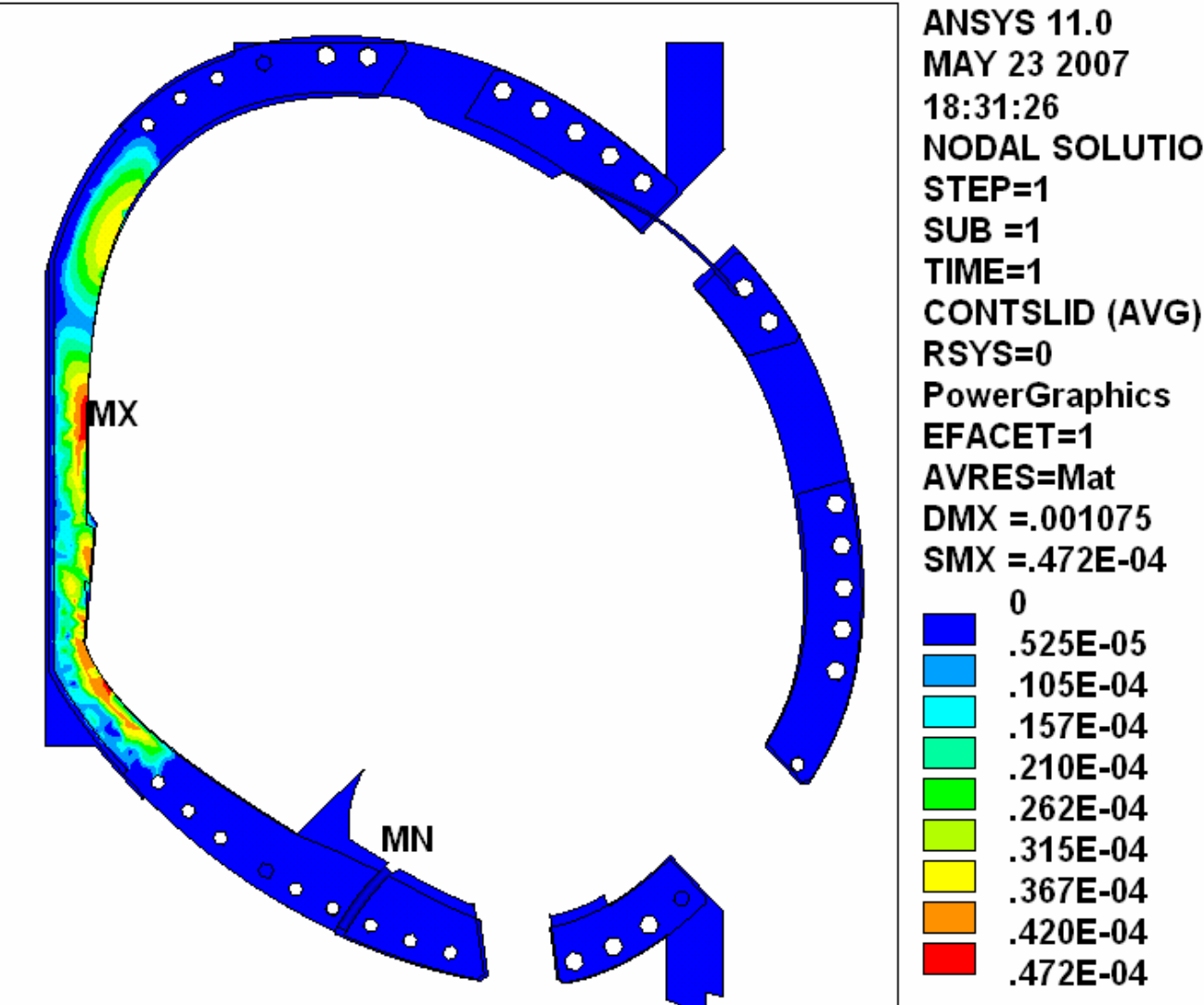


ANSYS 11.0  
 MAY 23 2007  
 18:22:08  
 NODAL SOLUTION  
 STEP=1  
 SUB =1  
 TIME=1  
 USUM (AVG)  
 RSYS=0  
 PowerGraphics  
 EFACET=1  
 AVRES=Mat  
 DMX =.001465  
 SMN =.925E-05  
 SMX =.001465



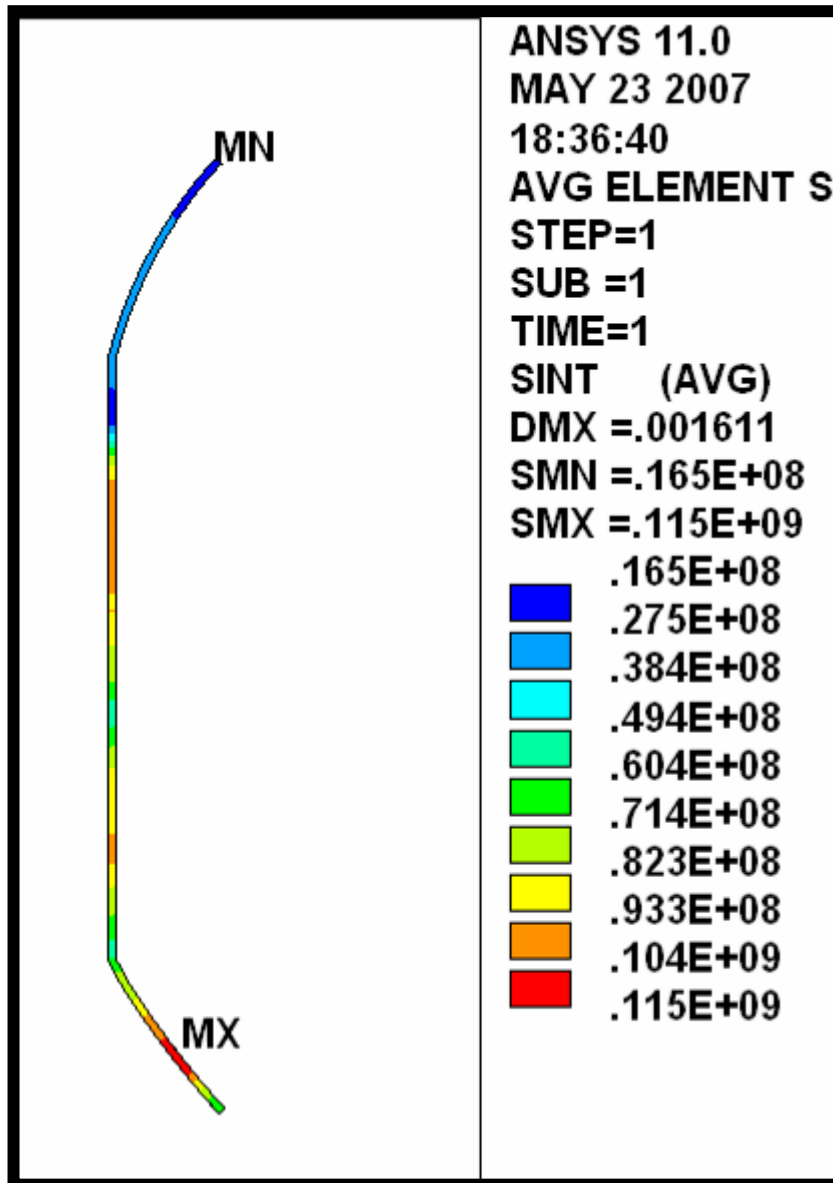
ANSYS 11.0  
 MAY 23 2007  
 18:22:08  
 NODAL SOLUTION  
 STEP=1  
 SUB =1  
 TIME=1  
 USUM (AVG)  
 RSYS=0  
 PowerGraphics  
 EFACET=1  
 AVRES=Mat  
 DMX =.001465  
 SMN =.925E-05  
 SMX =.001465

# Contact Sliding (Units are meters)



Peak sliding of .00185 in

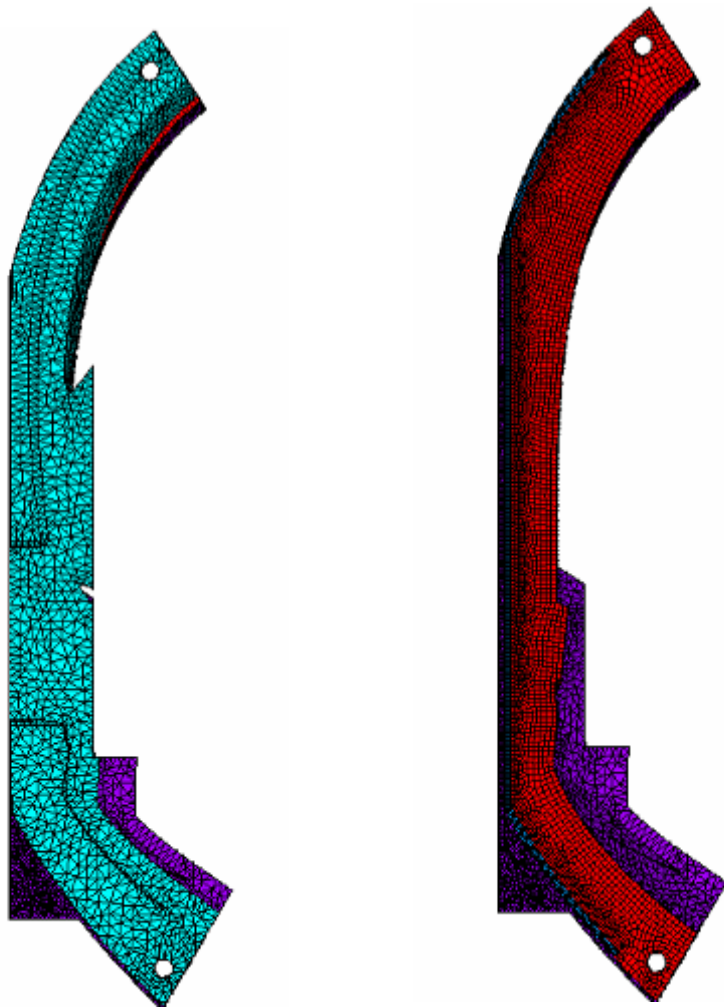
# Weld Stress intensity (Units are PA)



**Peak Stress of 16,680 psi**

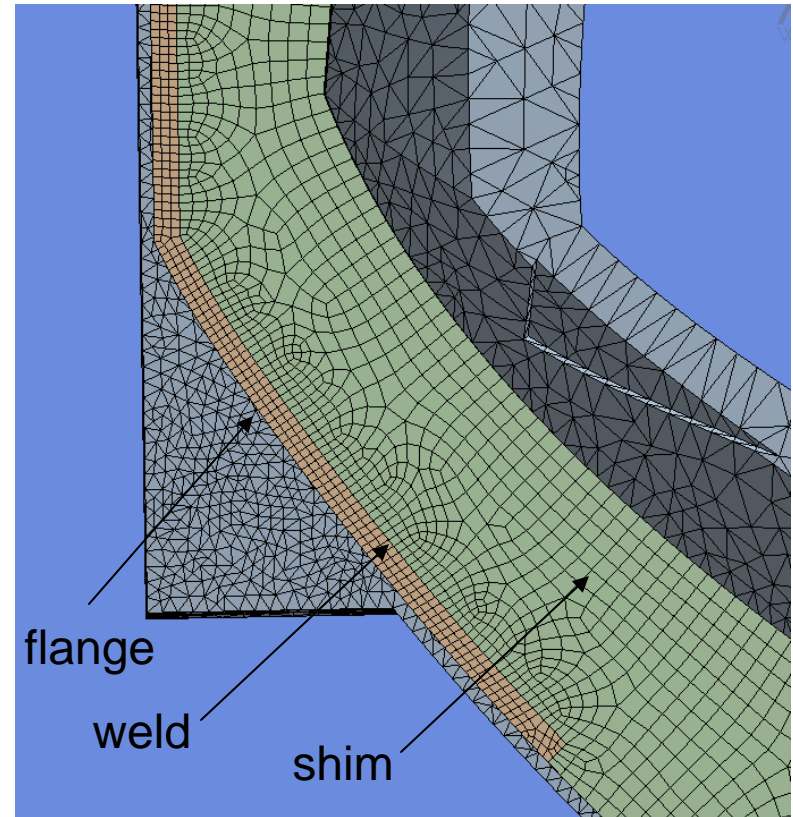


# SUBMODEL [Mesh of inboard leg of BC joint]



Complete sub model showing both flanges

Flange B removed

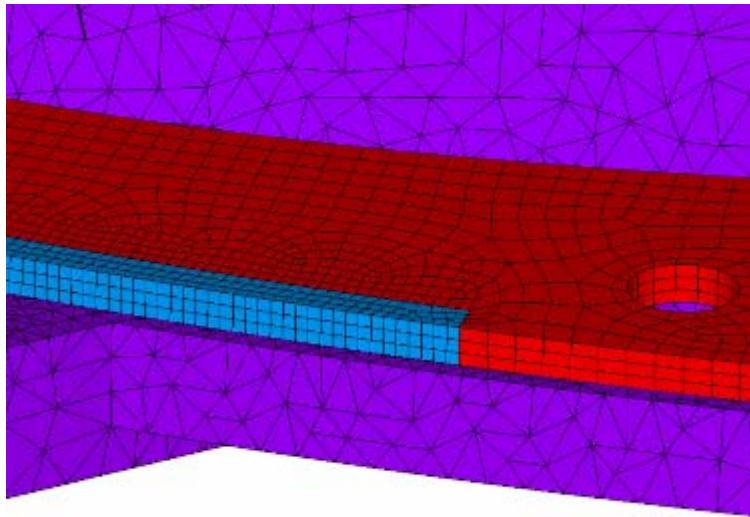


250,440 elements

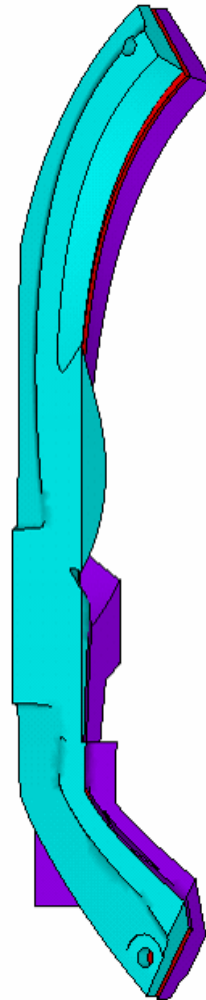
294,433 nodes



# Nodes that map boundary conditions from global model



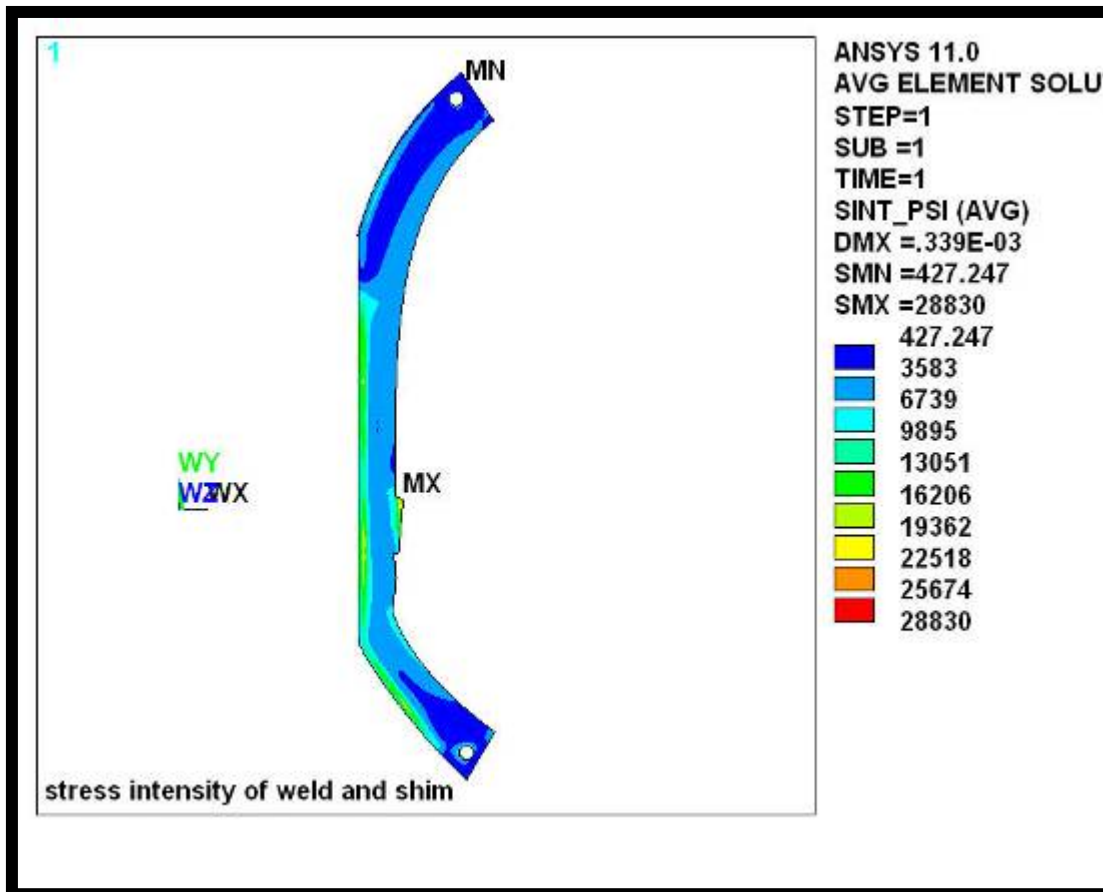
Mesh of weld is three elements thick, elements are higher order 20 node bricks.



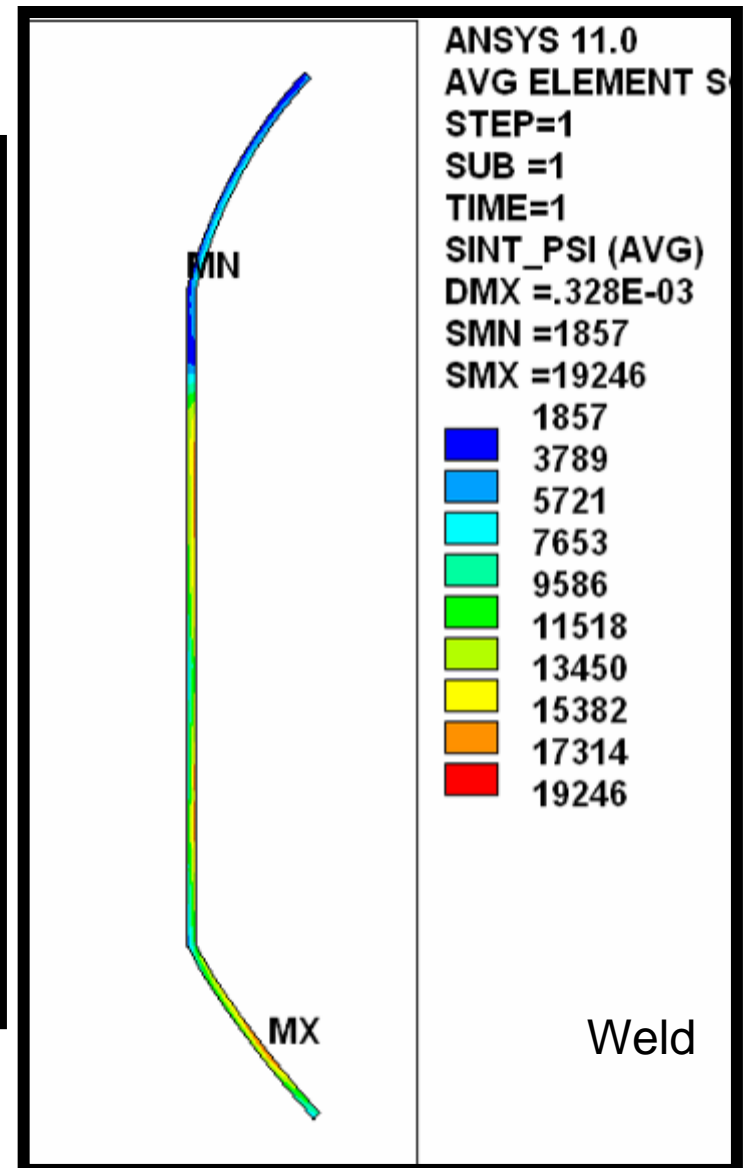
```
ANSYS 11.0  
COMPONENTS  
Set 1 of 1  
FACE_S1 (Nodes)  
FACE_S2 (Nodes)  
FACE_S3 (Nodes)  
FACE_S4 (Nodes)  
FACE_S5 (Nodes)  
FACE_S6 (Nodes)
```

Faces of which displacements are mapped too in the global model

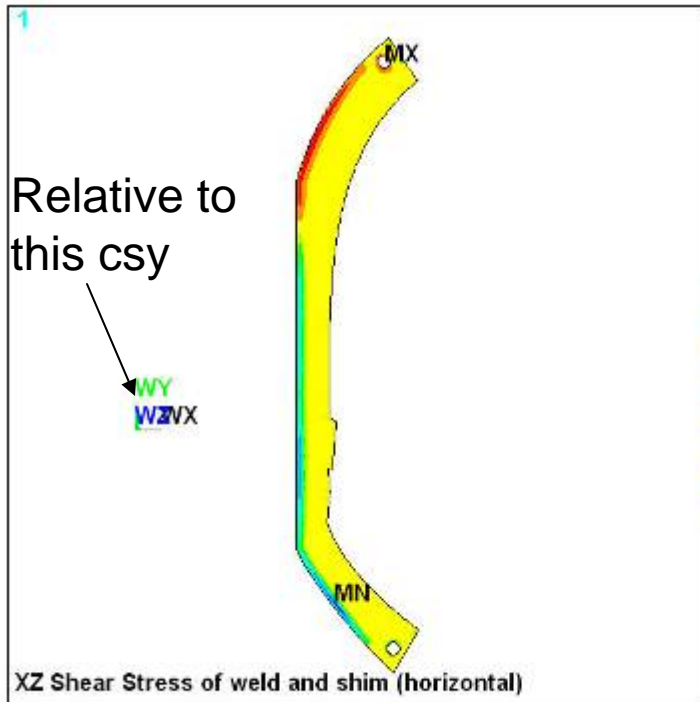
# Stress Intensity of weld (Units are PSI)



Weld and shim

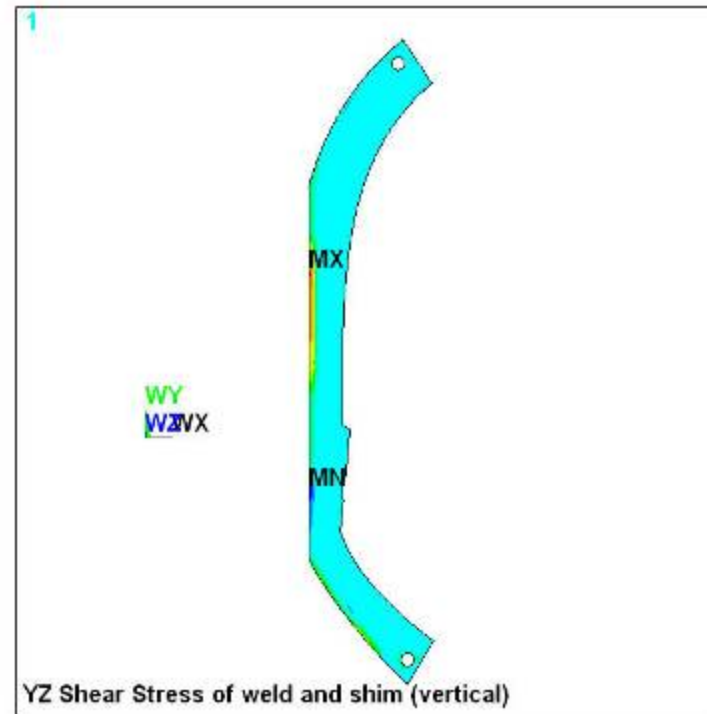


# XZ and YZ Shear Stress of weld and shim (Units are PSI)



ANSYS 11.0  
AVG ELEMENT SOLU'  
STEP=1  
SUB =1  
TIME=1  
SXZ\_PSI (AVG)  
DMX =.339E-03  
SMN =-8590  
SMX =3019

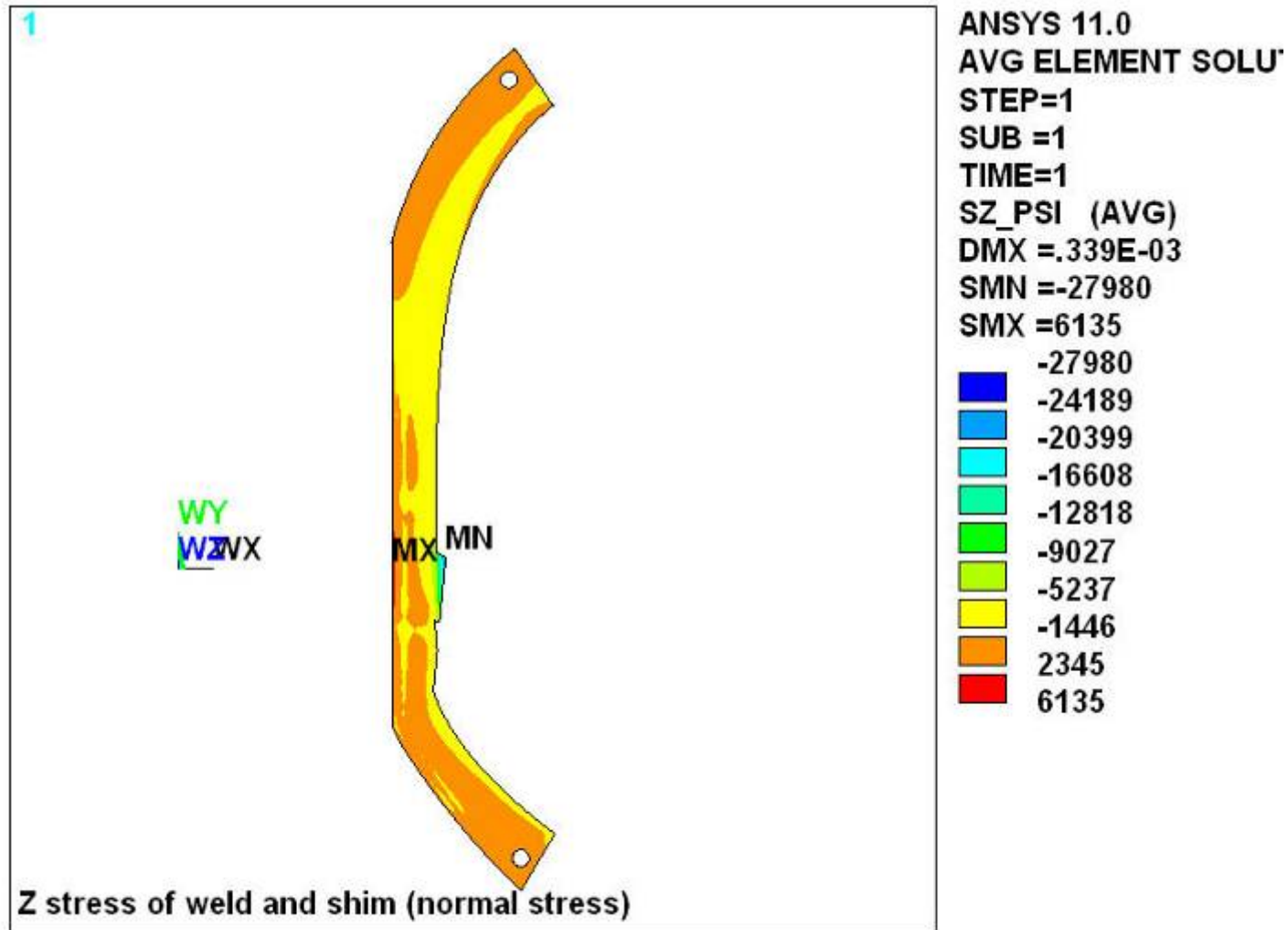
Blue	-8590
Light Blue	-7300
Cyan	-6010
Light Green	-4720
Green	-3430
Yellow-Green	-2140
Yellow	-850.463
Orange	439.48
Red-Orange	1729
Red	3019



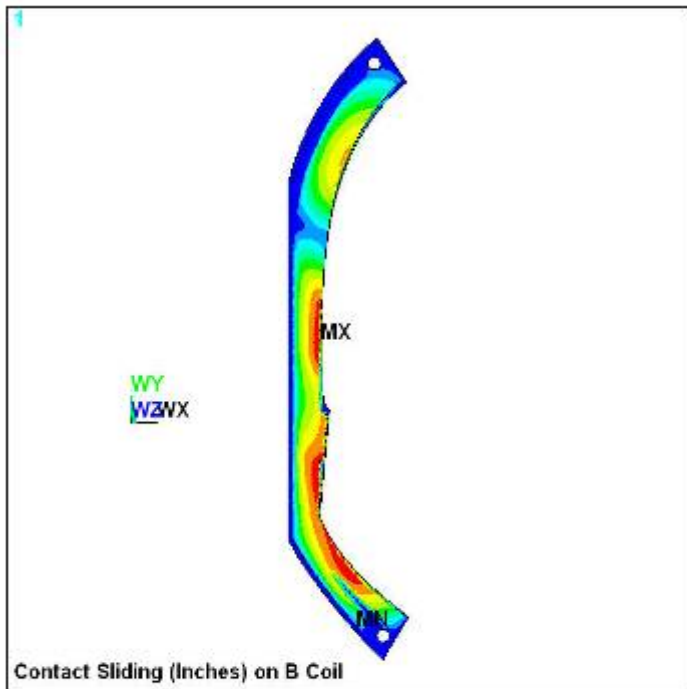
ANSYS 11.0  
AVG ELEMENT SOLU'  
STEP=1  
SUB =1  
TIME=1  
SYZ\_PSI (AVG)  
DMX =.339E-03  
SMN =-2632  
SMX =6010

Blue	-2632
Light Blue	-1672
Cyan	-711.559
Light Green	248.692
Green	1209
Yellow-Green	2169
Yellow	3129
Orange	4090
Red-Orange	5050
Red	6010

# Normal Stress (Z) (Units are PSI)



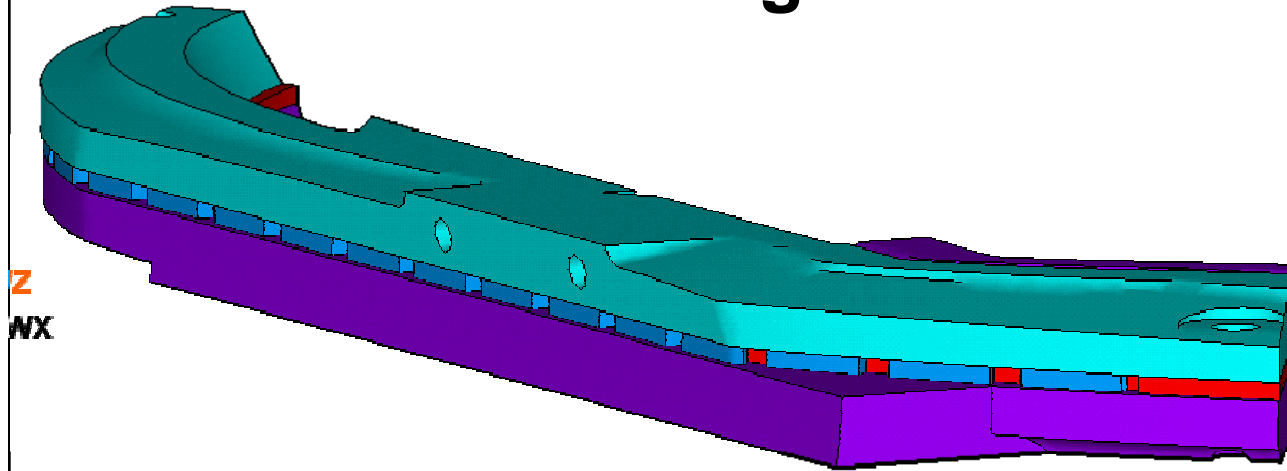
# Contact Sliding of shim on both flanges (inches)



## Quick weld allowable calculation based on BC weld

- $S_m = 2/3 S_y$  at temp or  $1/3 S_{ult}$  for all materials
- $S_y = 93.2$  ksi for stainless steel but weld since  $S_{ult}$  is 157.5  $\rightarrow S_m = 52.5$  based on weld wire.
- Knockdown factor of .6 applied for visual inspected welds.  $\rightarrow$  **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

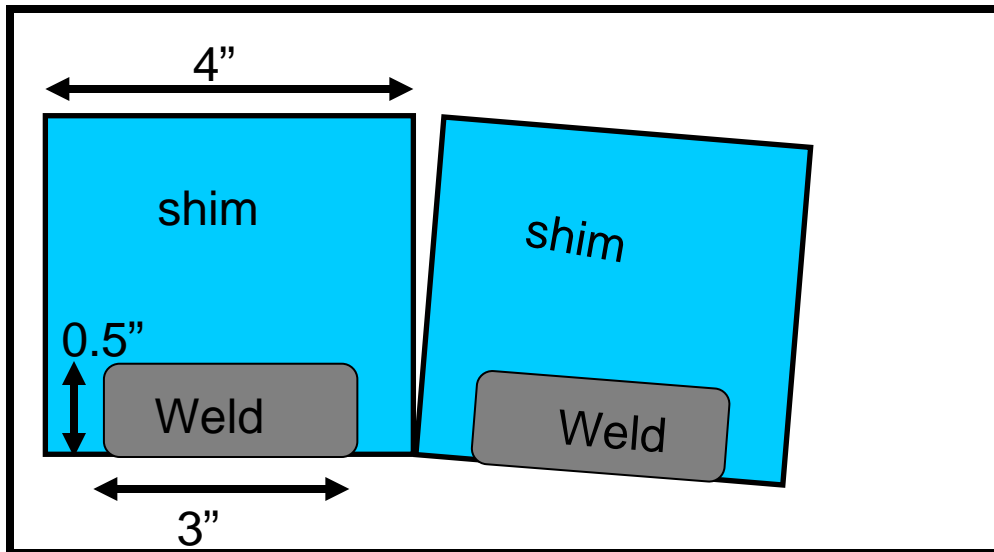
# Segmented Weld



weld

shim

## Weld shim sketch



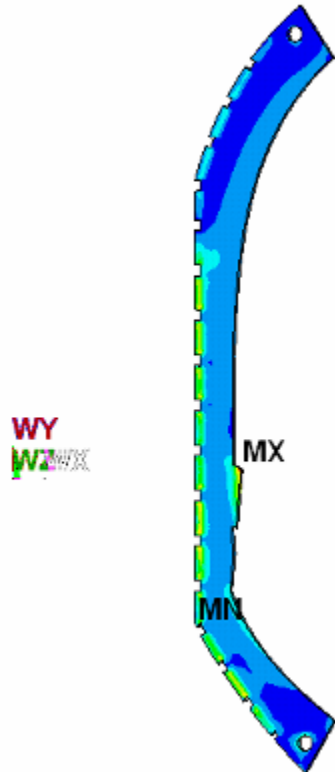
3 in  
1 in  
gap





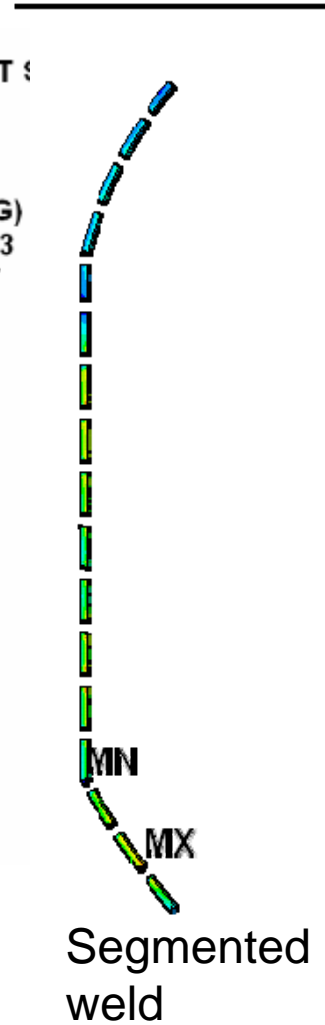
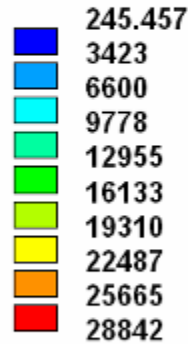
# Stress Intensity with segmented weld (0.5") (Units are psi)

1



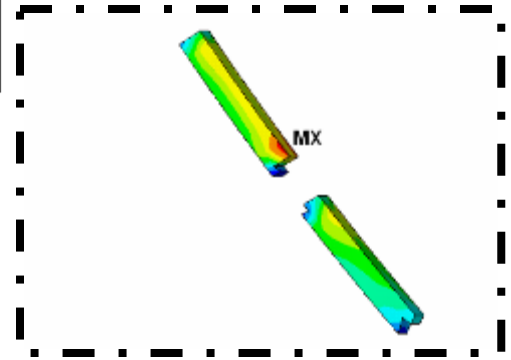
Stress Intensity for segmented weld

ANSYS 11.0  
AVG ELEMENT S  
STEP=1  
SUB =1  
TIME=1  
SINT\_PSI (AVG)  
DMX =.364E-03  
SMN =245.457  
SMX =28842



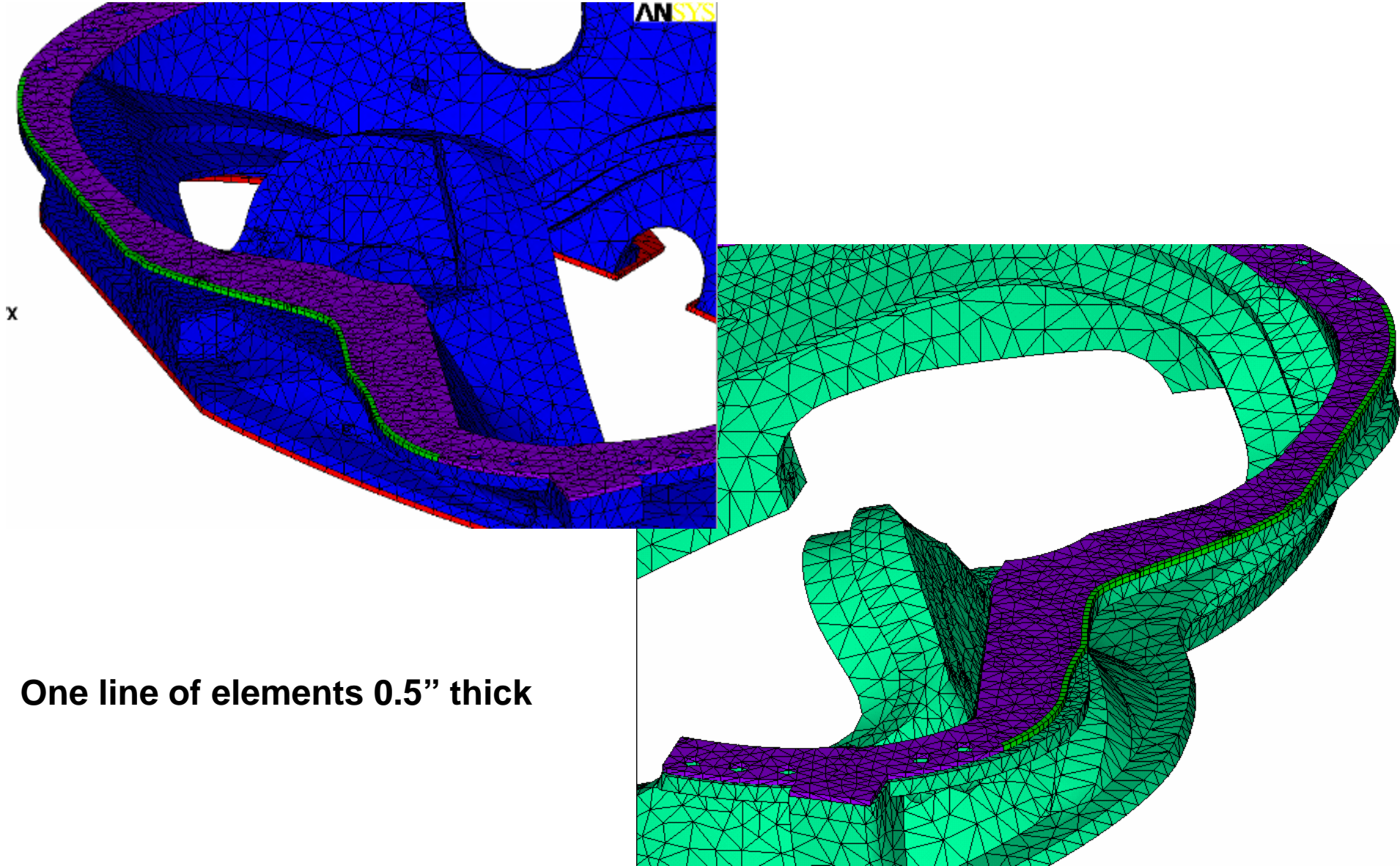
Segmented weld

ANSYS 11.0  
AVG ELEMENT S  
STEP=1  
SUB =1  
TIME=1  
SINT\_PSI (AVG)  
DMX =.364E-03  
SMN =245.457  
SMX =25348



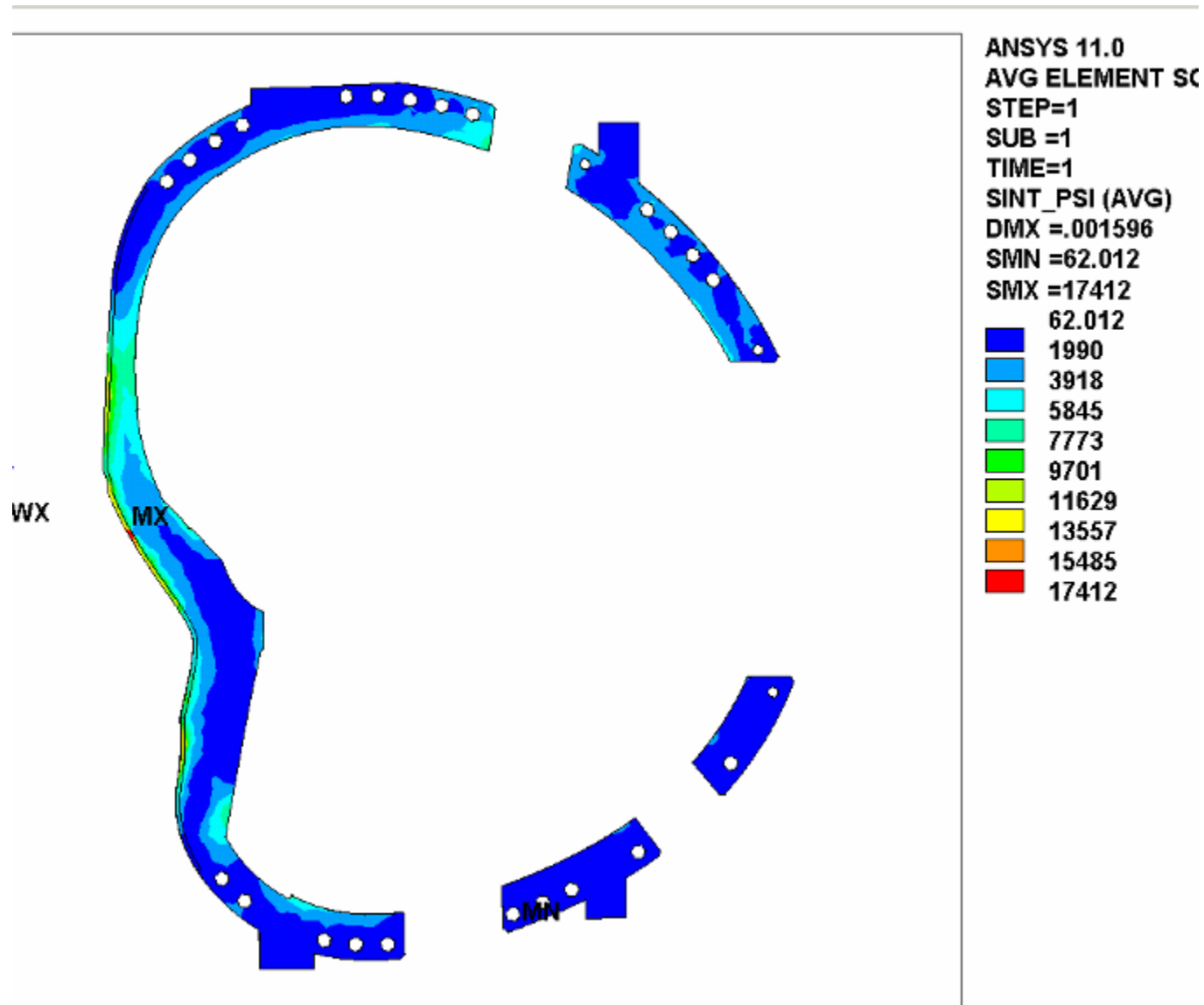
Stress Increases from 19.2 to 25.3 ksi  
with added segmentation

# AB Weld model (same method as BC)

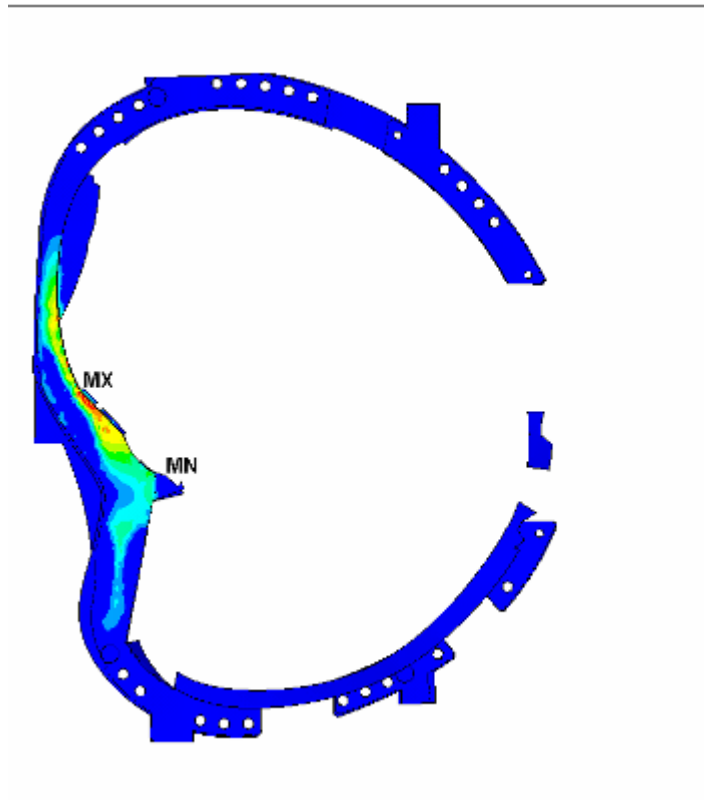


One line of elements 0.5" thick

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

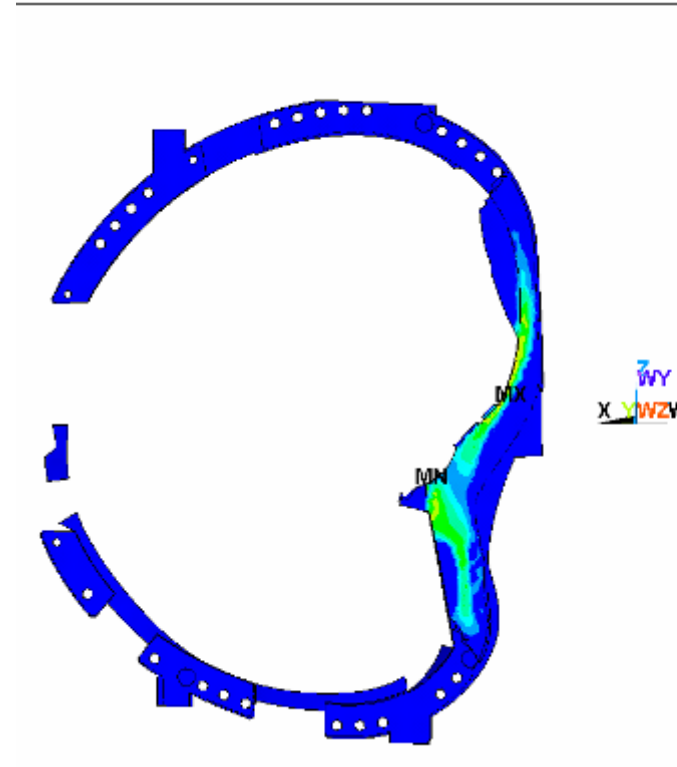


# Sliding (Units are inches)



Looking from A

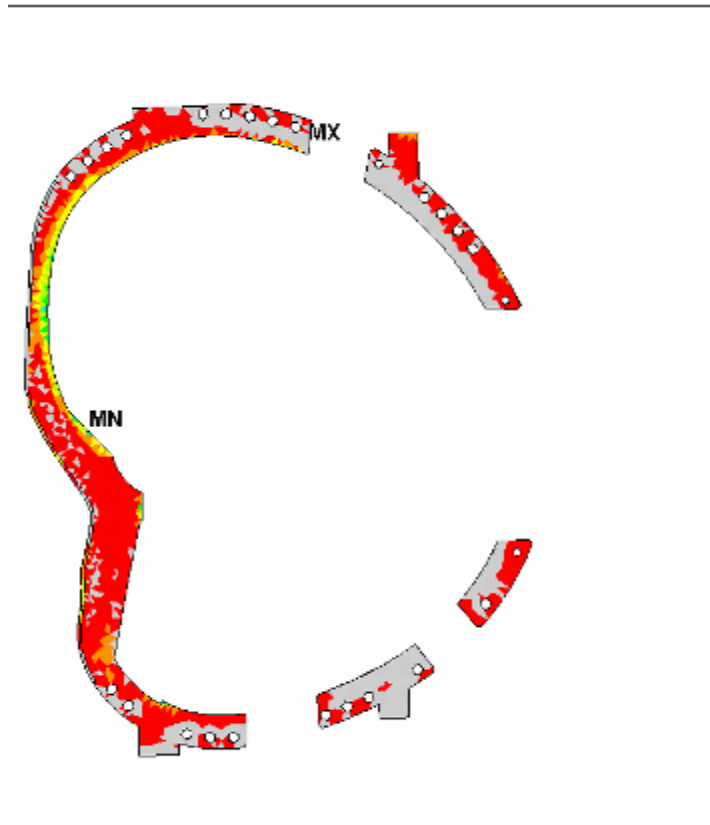
ANSYS 11.0  
AVG ELEMENT SOL  
STEP=1  
SUB =1  
TIME=1  
CONT\_IN (AVG)  
DMX =.001596  
SMX =.002784  
0  
.309E-03  
.619E-03  
.928E-03  
.001237  
.001547  
.001856  
.002166  
.002475  
.002784



Looking from B

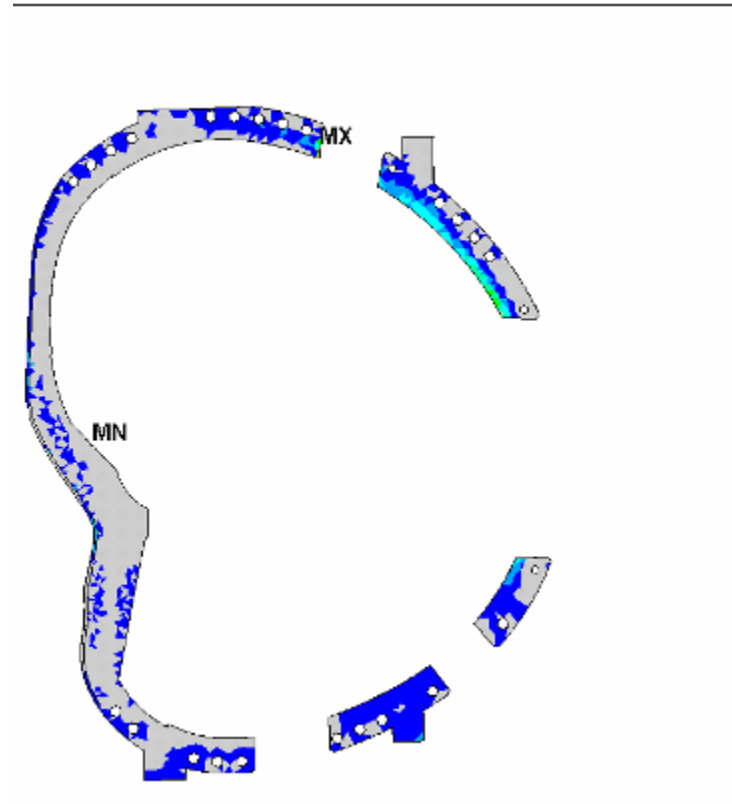
ANSYS 11.0  
AVG ELEMENT SOL  
STEP=1  
SUB =1  
TIME=1  
CONT\_IN (AVG)  
DMX =.001596  
SMX =.002784  
0  
.309E-03  
.619E-03  
.928E-03  
.001237  
.001547  
.001856  
.002166  
.002475  
.002784

# Normal Stress (Units are psi)



Grey = tension

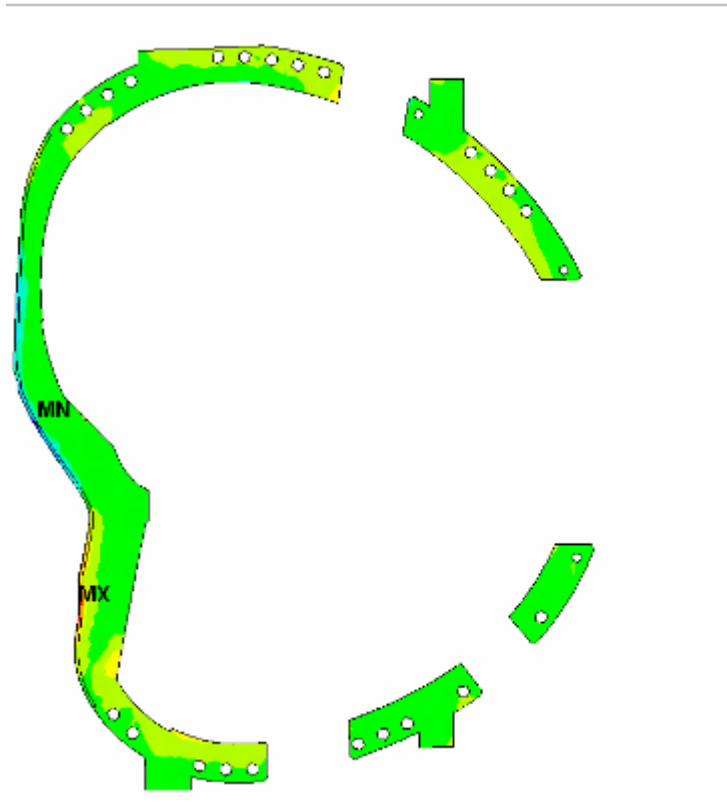
ANSYS 11.0  
ELEMENT SOLU  
STEP=1  
SUB =1  
TIME=1  
NORMAL\_S (NO  
DMX =.001596  
SMN =-11700  
SMX =7639  
-11700  
-10400  
-9100  
-7800  
-6500  
-5200  
-3900  
-2600  
-1300  
0



Grey = compression

ANSYS 11.0  
ELEMENT SOLU  
STEP=1  
SUB =1  
TIME=1  
NORMAL\_S (NK  
DMX =.001596  
SMN =-11700  
SMX =7639  
0  
848.778  
1698  
2546  
3395  
4244  
5093  
5941  
6790  
7639

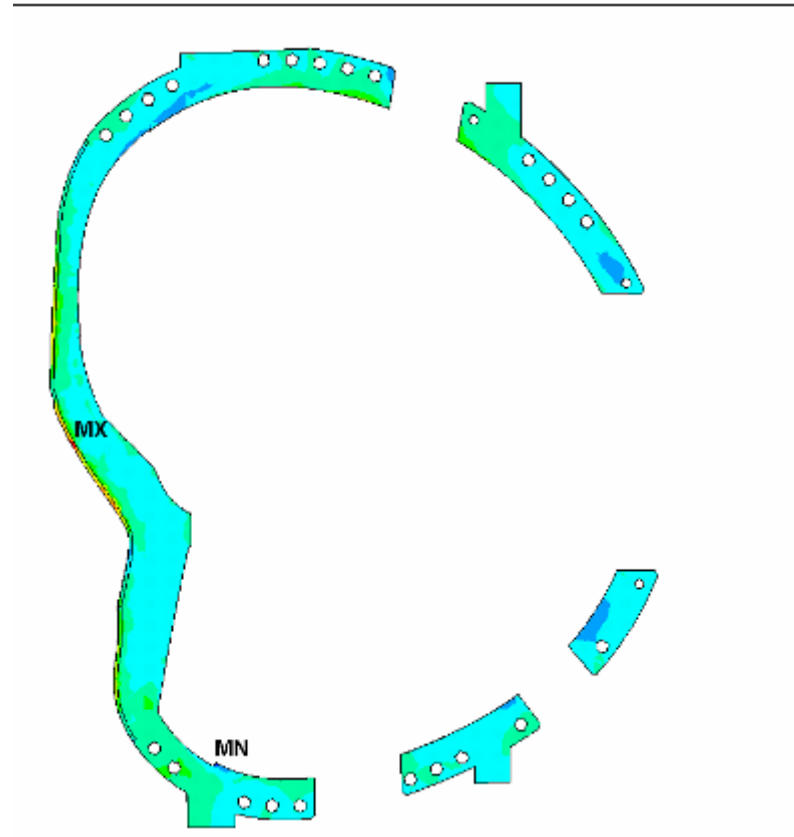
# Shear Stresses (psi)



ANSYS 11.0  
AVG ELEMENT \$  
STEP=1  
SUB =1  
TIME=1  
SXZ\_PSI (AVG)  
DMX =.001596  
SMN =-7800  
SMX =6460

Blue	-7800
Light Blue	-6215
Cyan	-4631
Light Green	-3046
Green	-1462
Yellow-Green	122.448
Yellow	1707
Orange	3291
Red-Orange	4876
Red	6460

SXZ (horizontal shear)



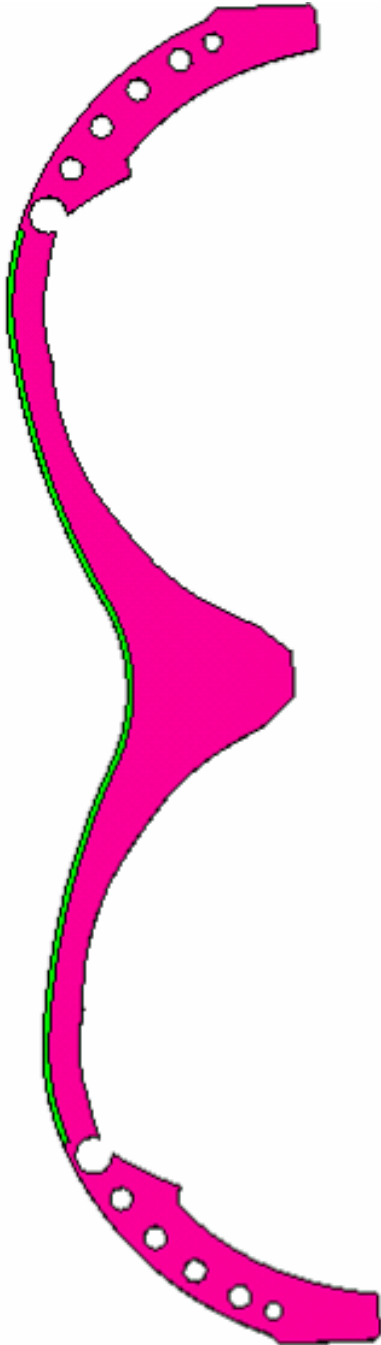
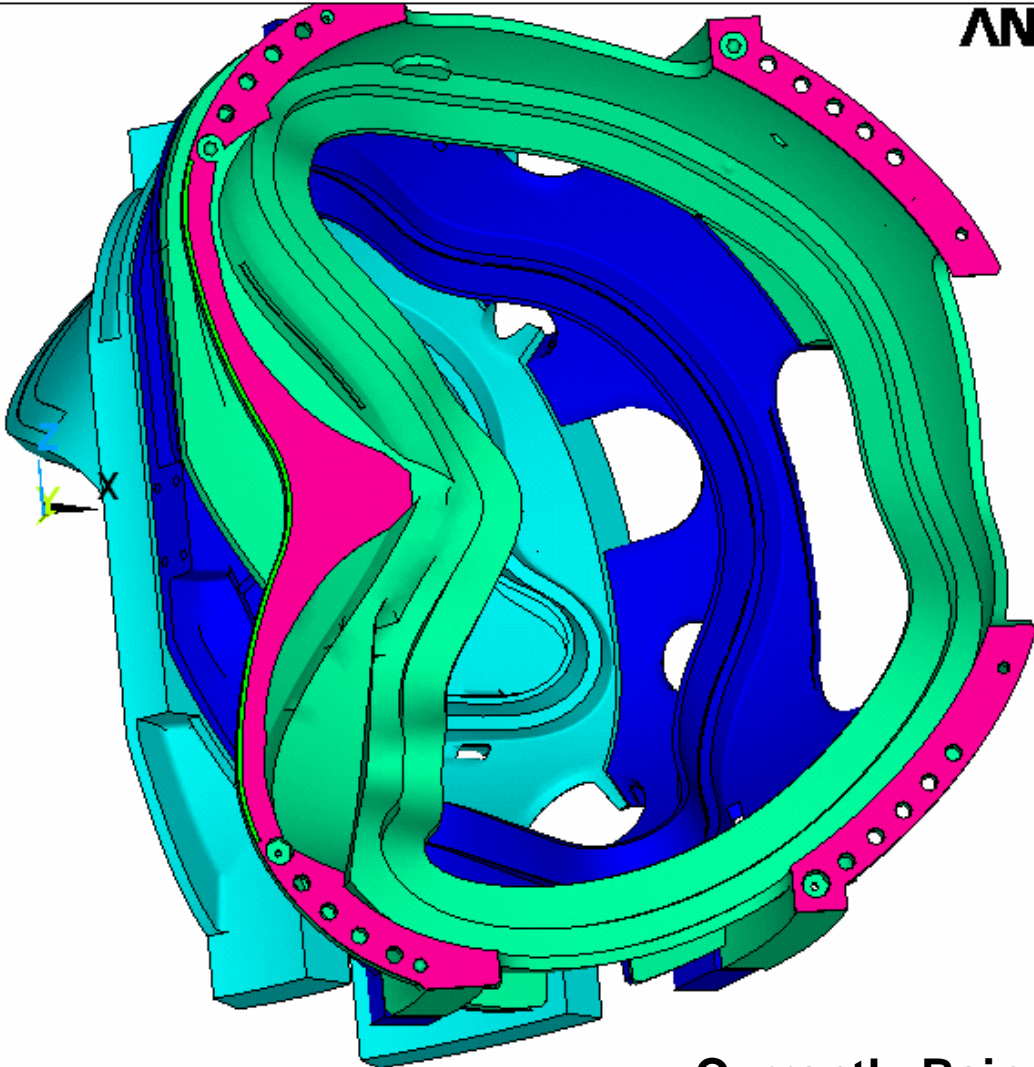
ANSYS 11.0  
AVG ELEMENT \$  
STEP=1  
SUB =1  
TIME=1  
SYZ\_PSI (AVG)  
DMX =.001596  
SMN =-1779  
SMX =3590

Blue	-1779
Light Blue	-1182
Cyan	-585.865
Light Green	10.649
Green	607.163
Yellow-Green	1204
Yellow	1800
Orange	2397
Red-Orange	2993
Red	3590

SYZ (vertical shear)

# AA Weld

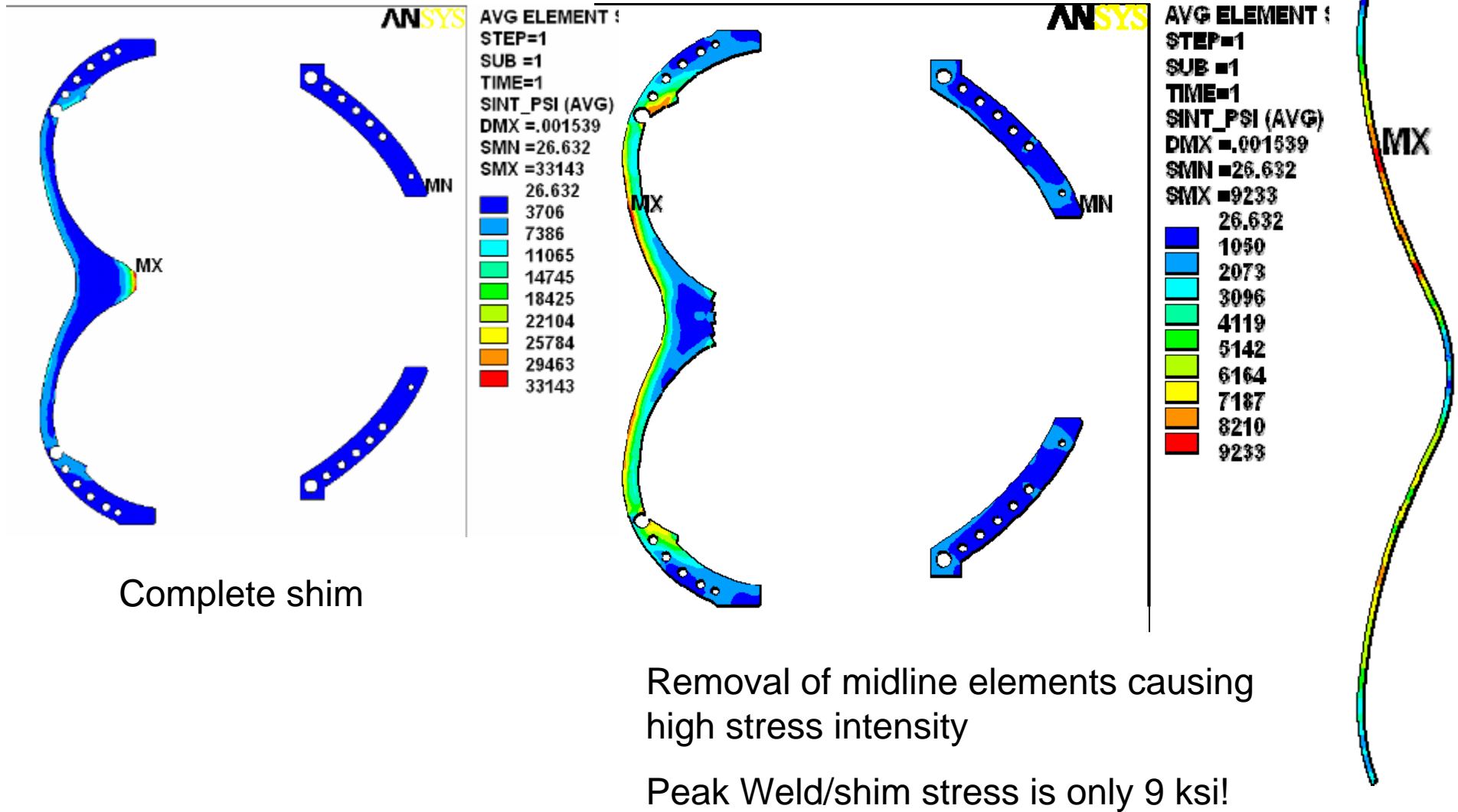
ANSYS



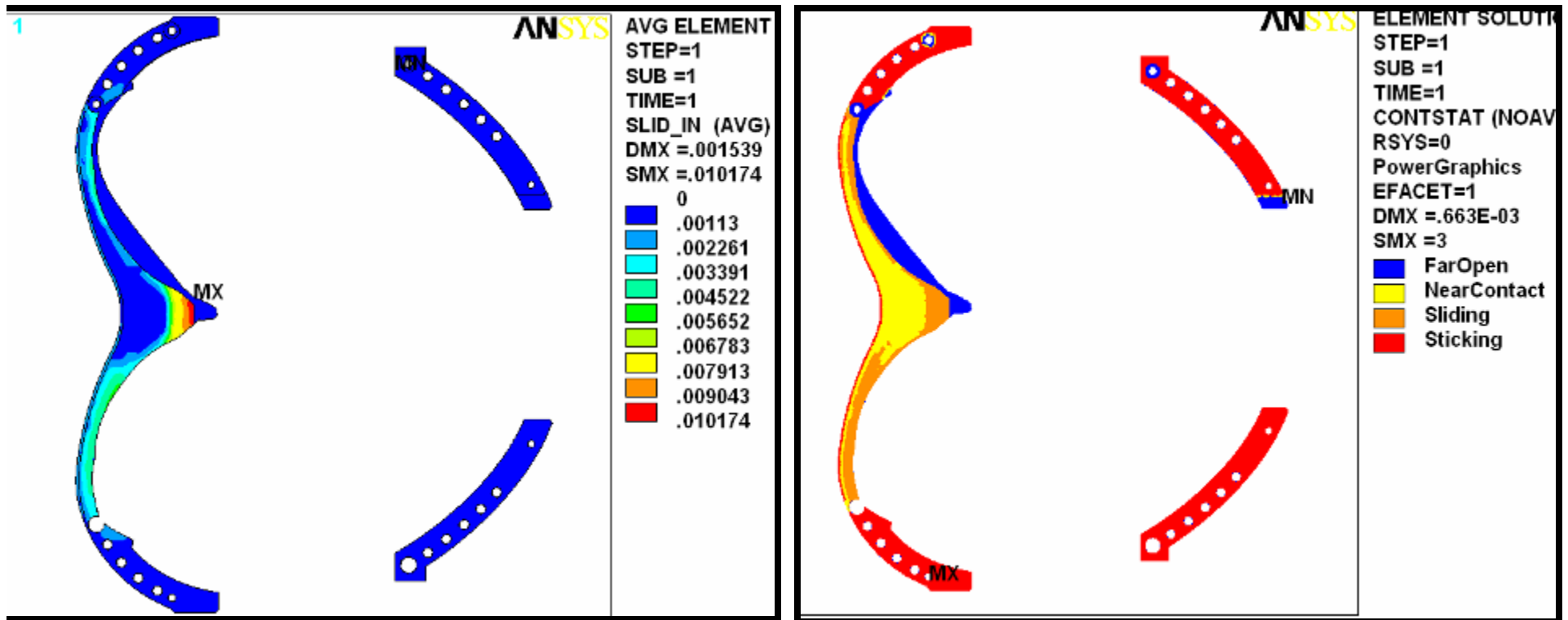
Currently Being Solved



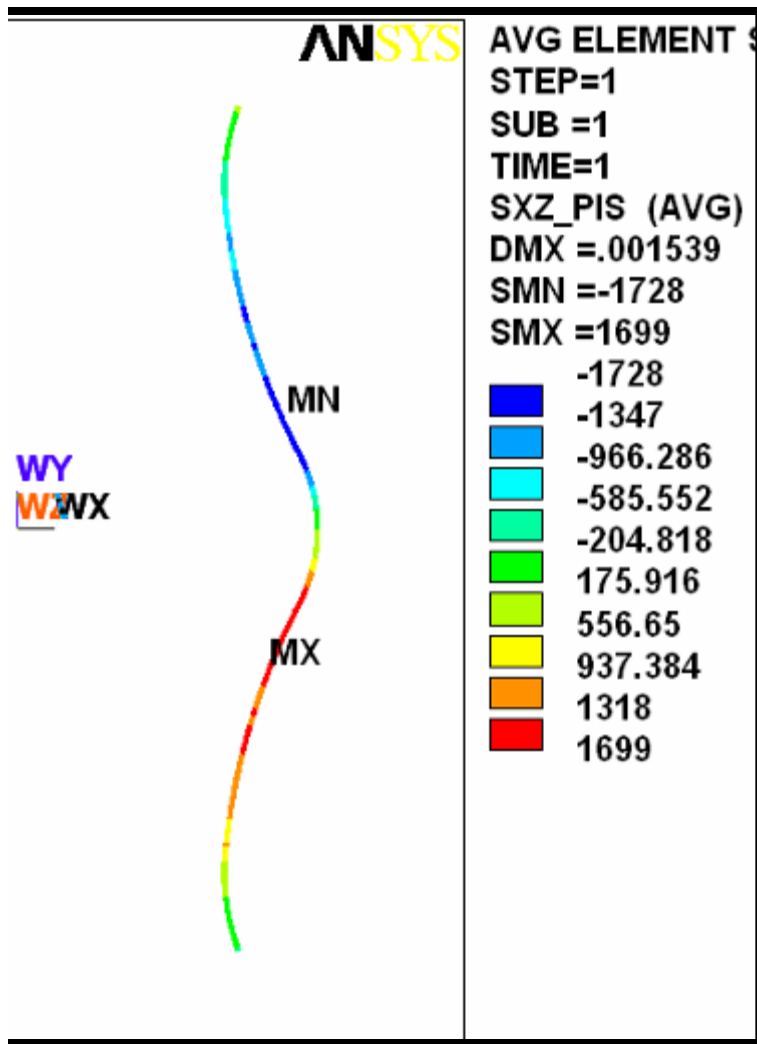
# AA Stress Intensity of Weld and shim (units are Psi)



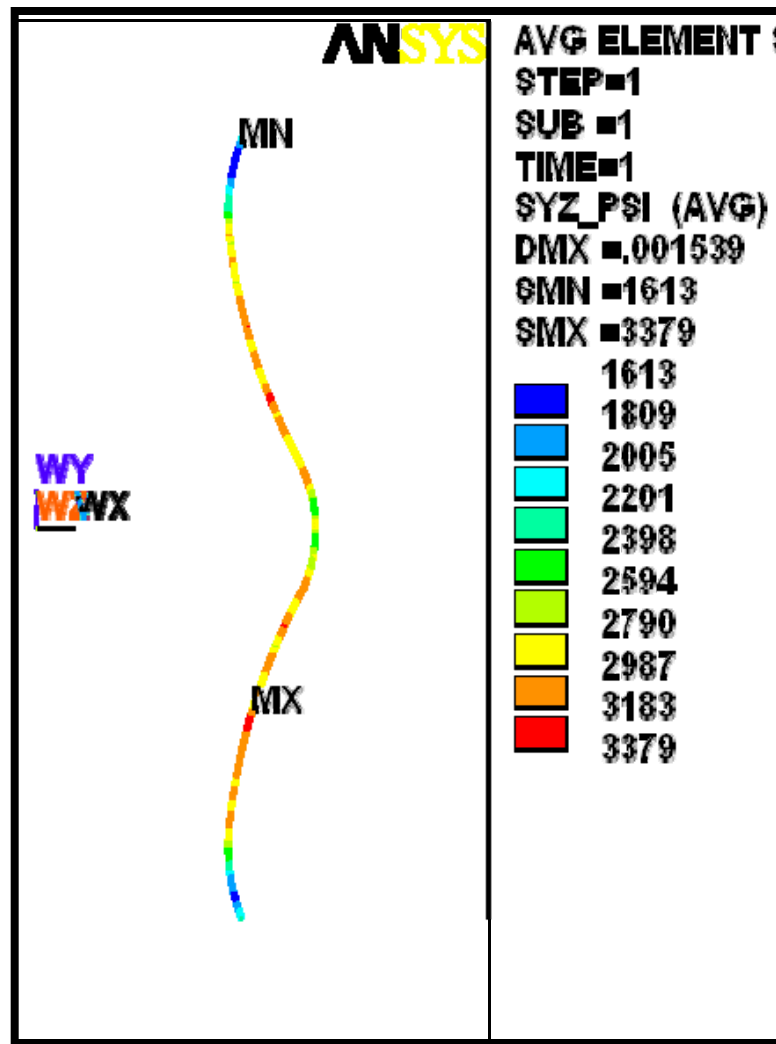
# AA Sliding and contact status (inches)



# AA Weld Shear Stresses (psi)

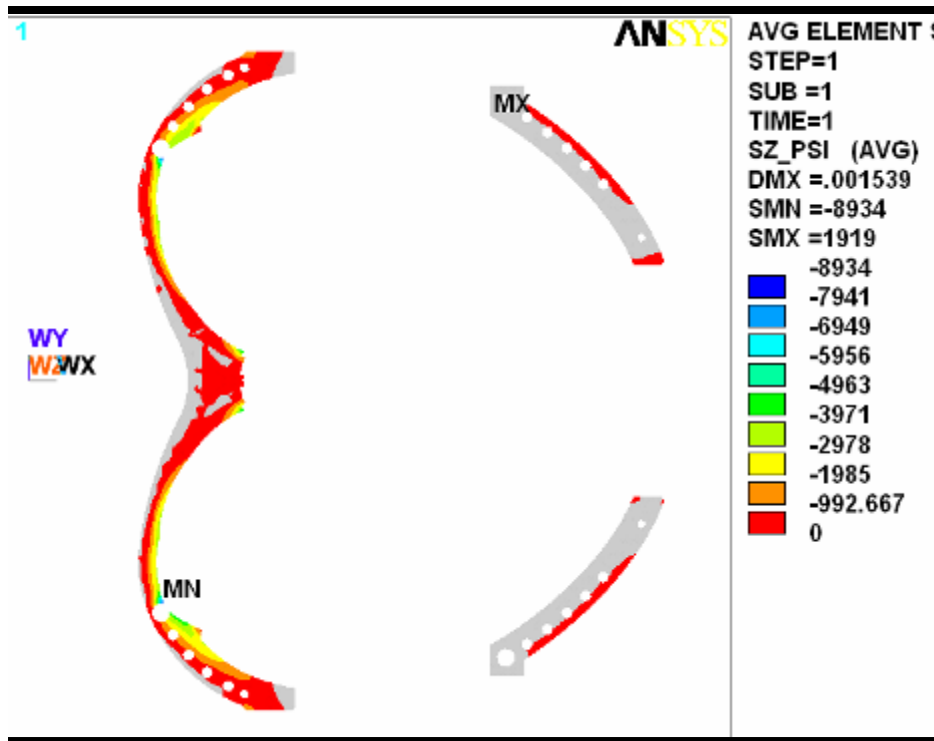


SXZ (horizontal shear)

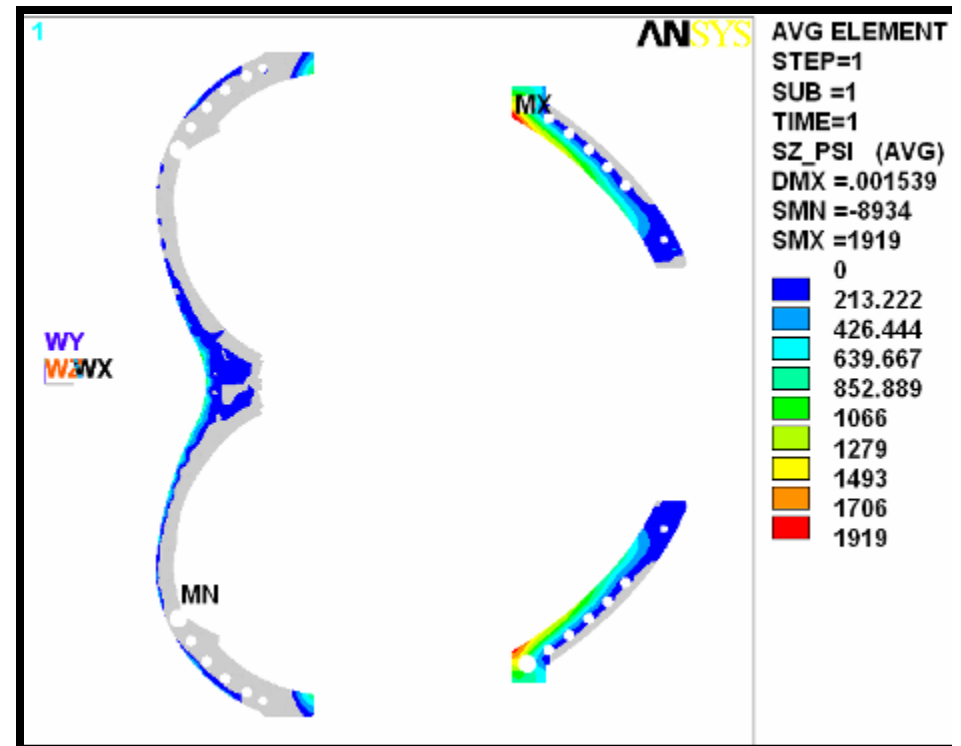


SYZ (vertical shear)

# AA Normal Stress (Units are psi)



Grey = tension



Grey = compression

## Next For welding

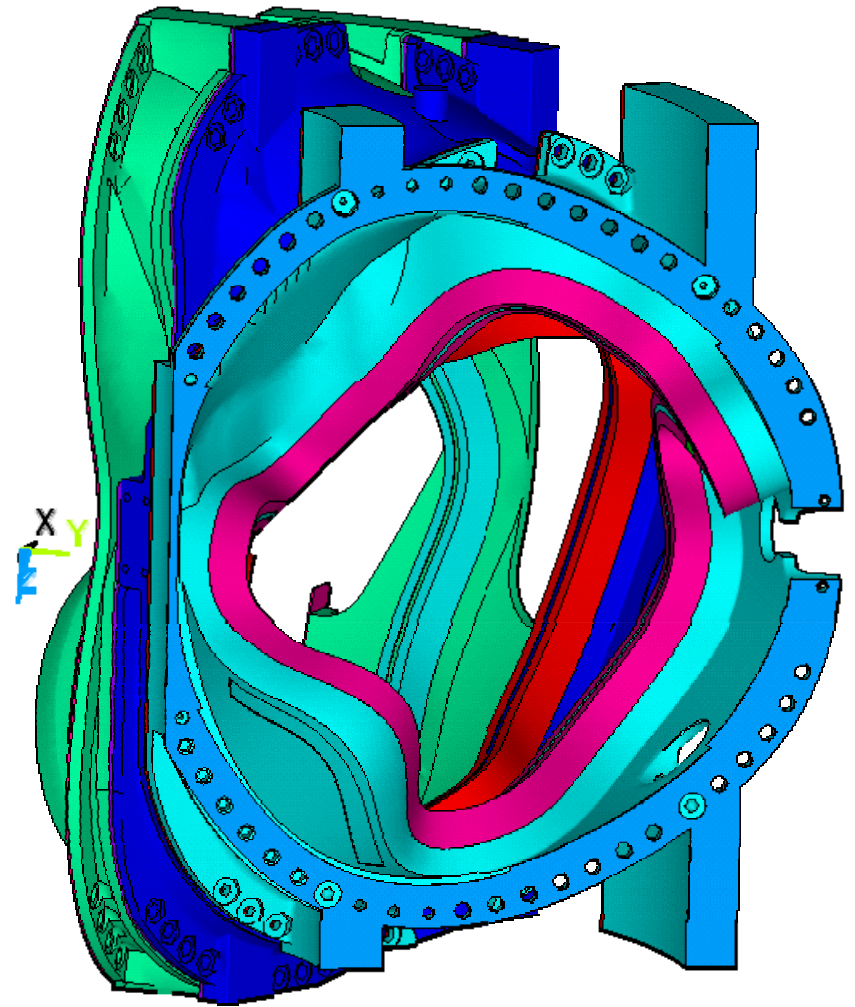
- Still need sub model of AB weld with correct weld geom. (need guidance from design team on shape) (type 2 in places?)
- Weld stresses on AA are low and there is little use for a sub model. **Weld AA is done**
- **Weld BC is done** (global, sub model and segmented).
- **Therefore the only remaining 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**

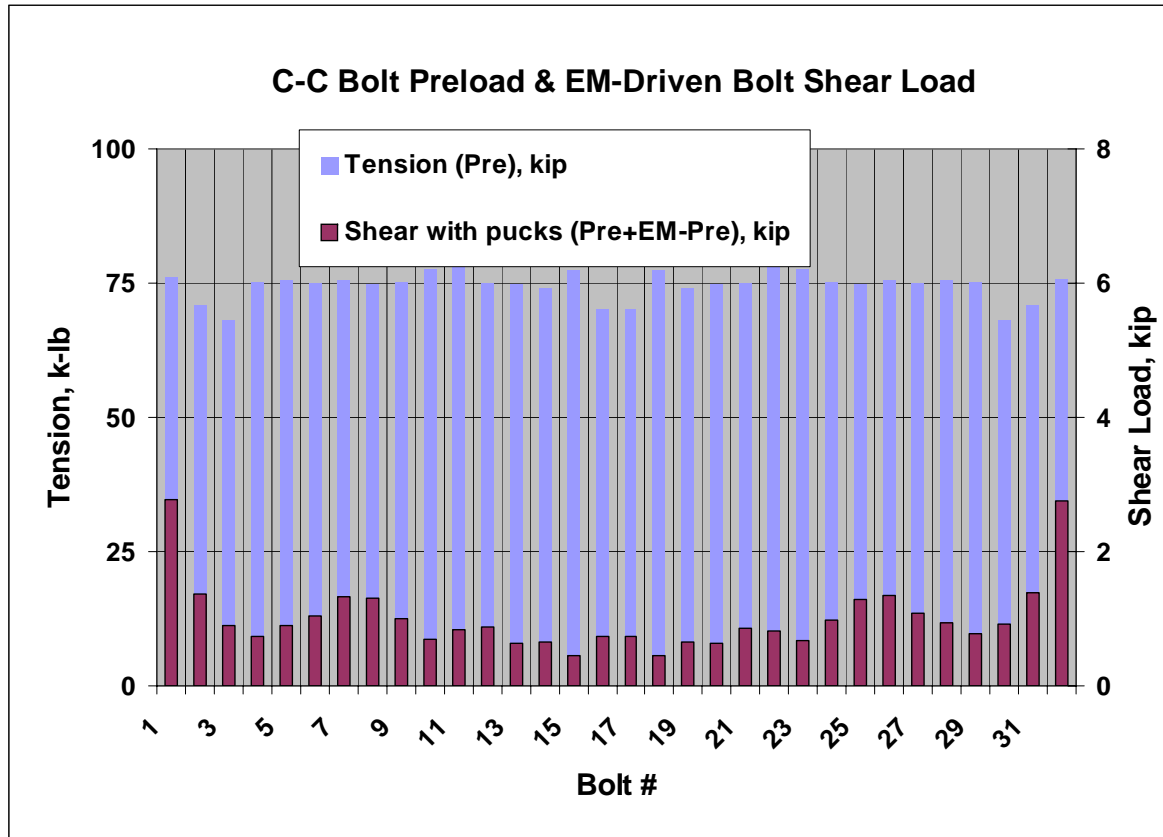
## Options to restrain movement of inboard leg.

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





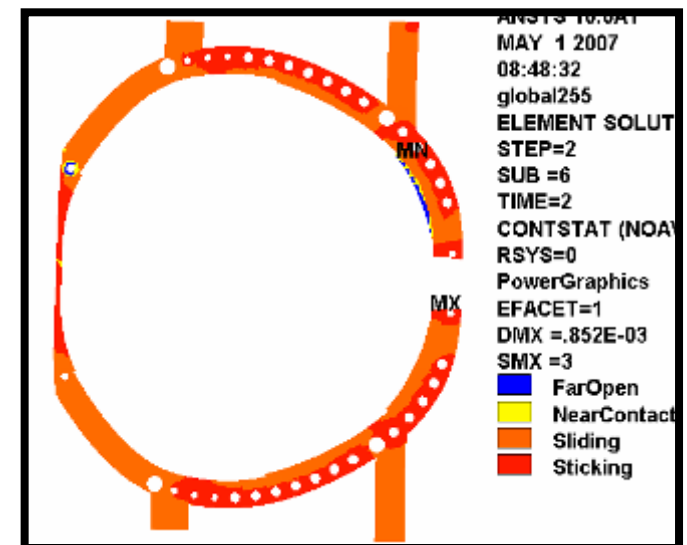
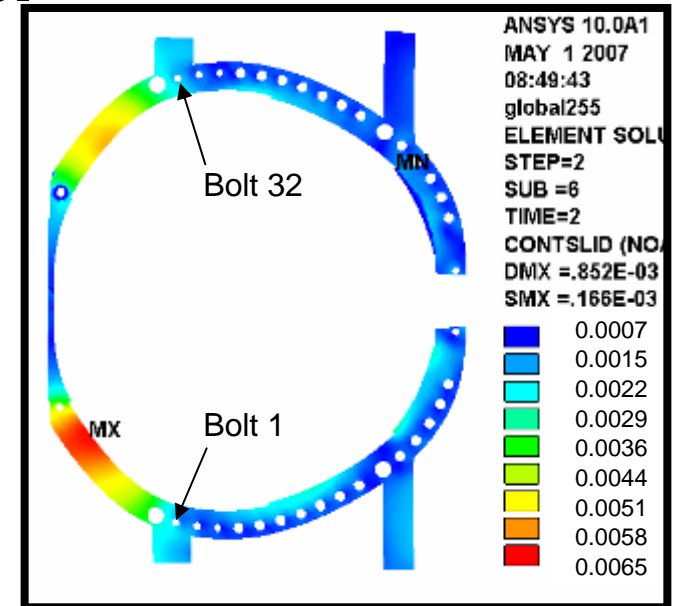
# Friction = 0.4 everywhere on flange through alumina shims.



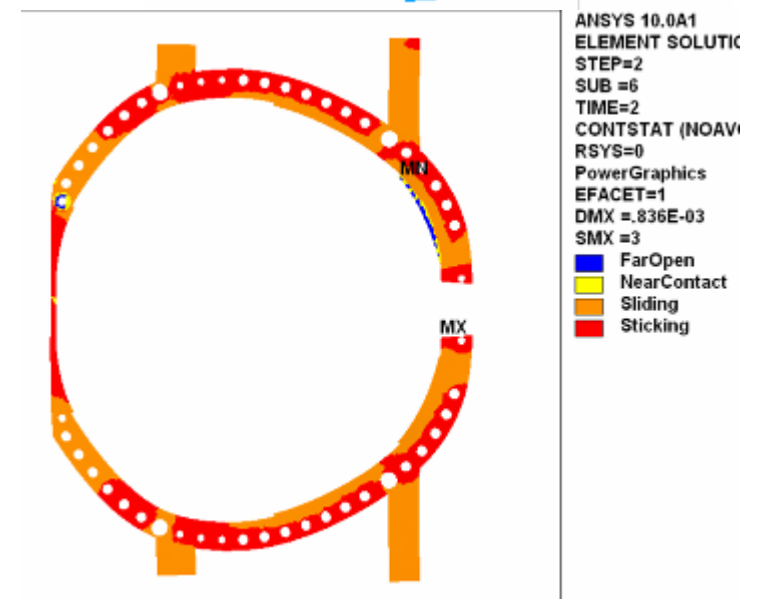
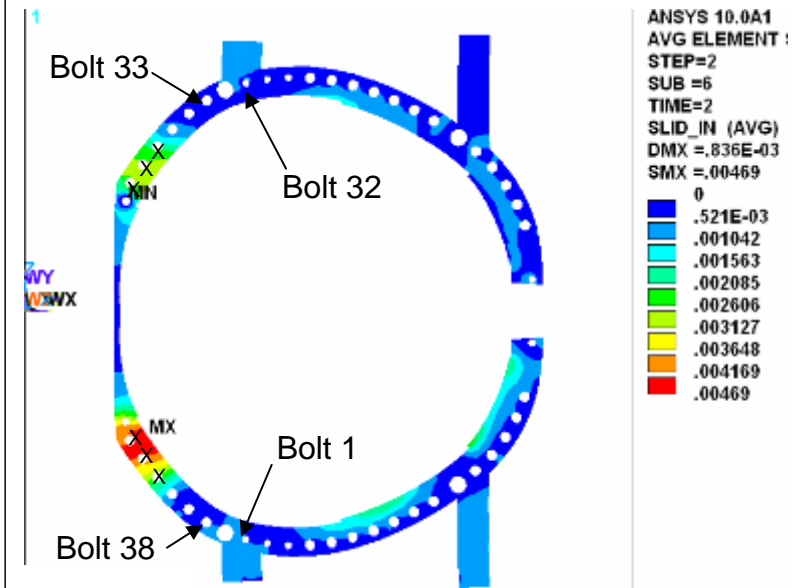
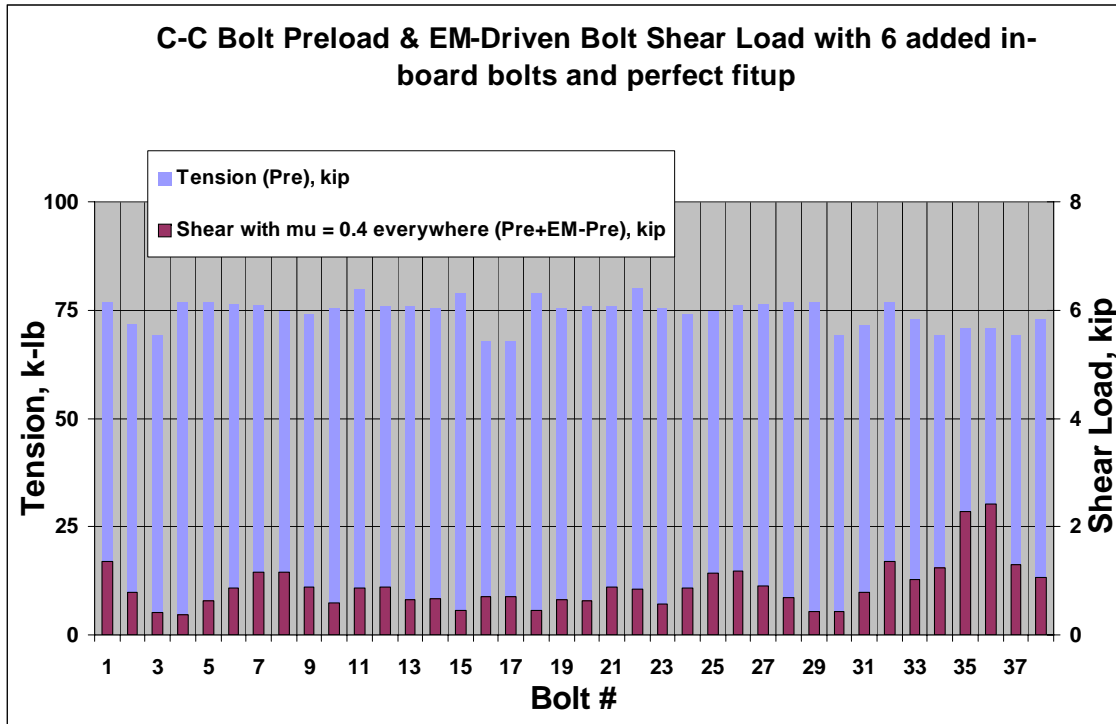
**NO INBOARD BOLTS**

Peak Load is 2.8 kips

Sliding is 6.5 mils



# Friction = 0.4 everywhere on flange through alumina shims.



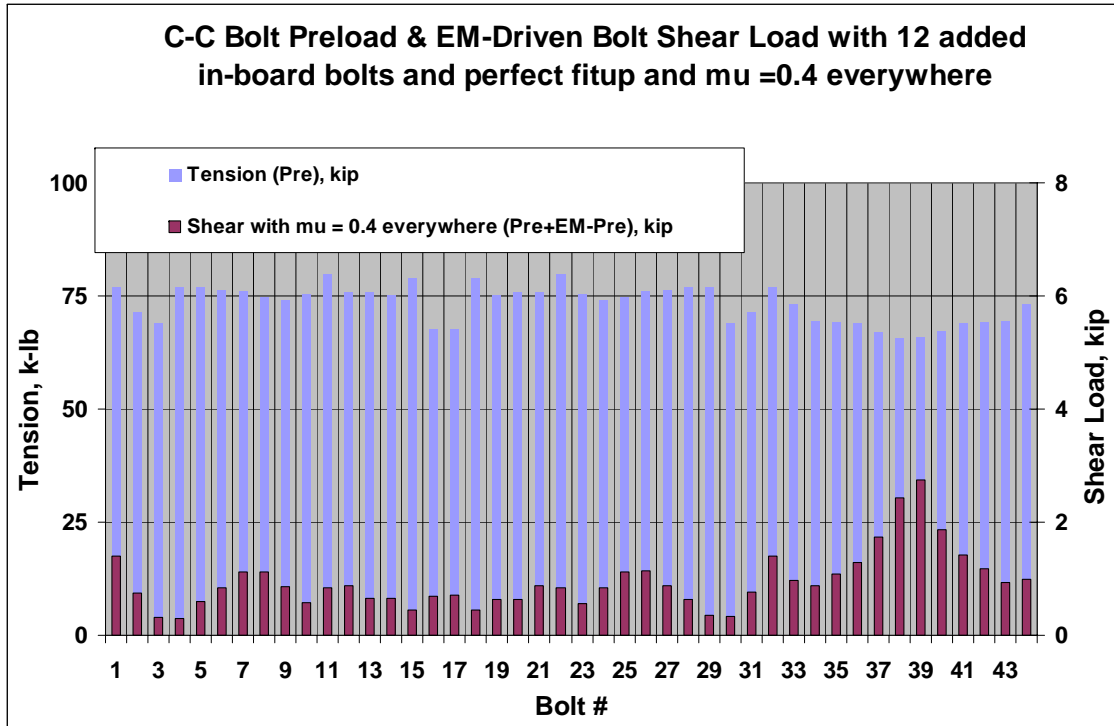
## ADDED 6 Inboard Bolts

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

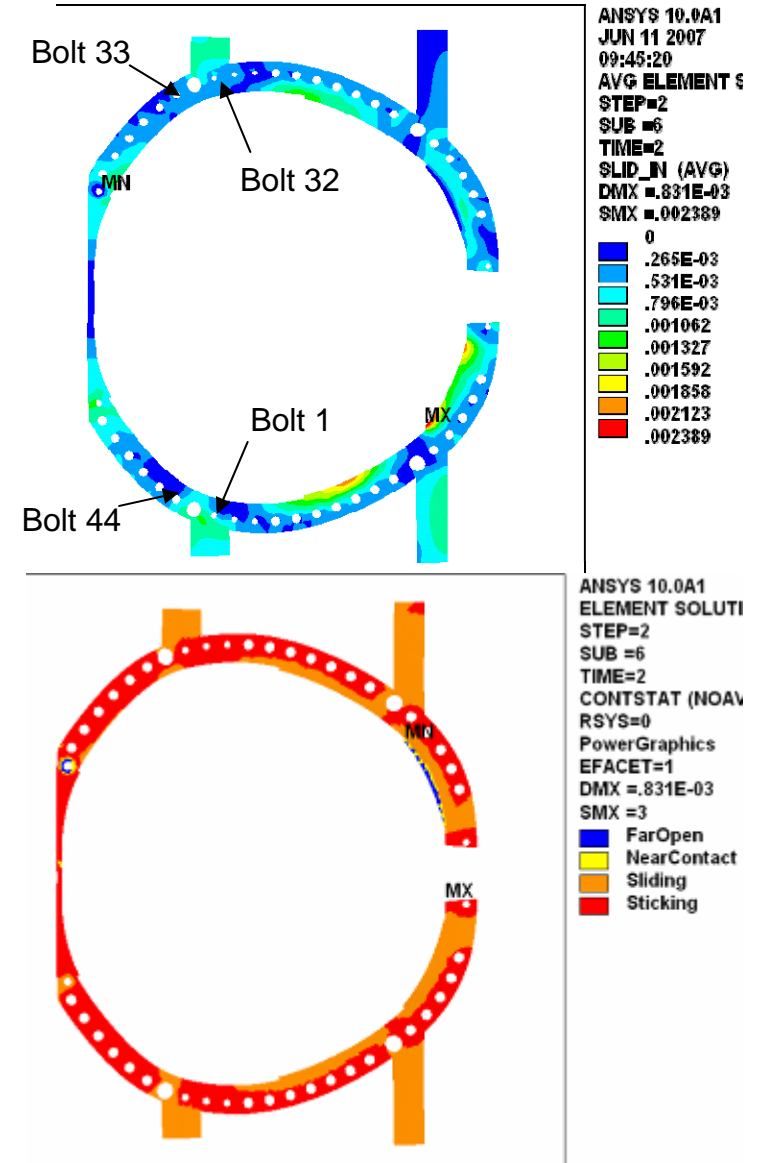
# Friction = 0.4 everywhere on flange through alumina shims.



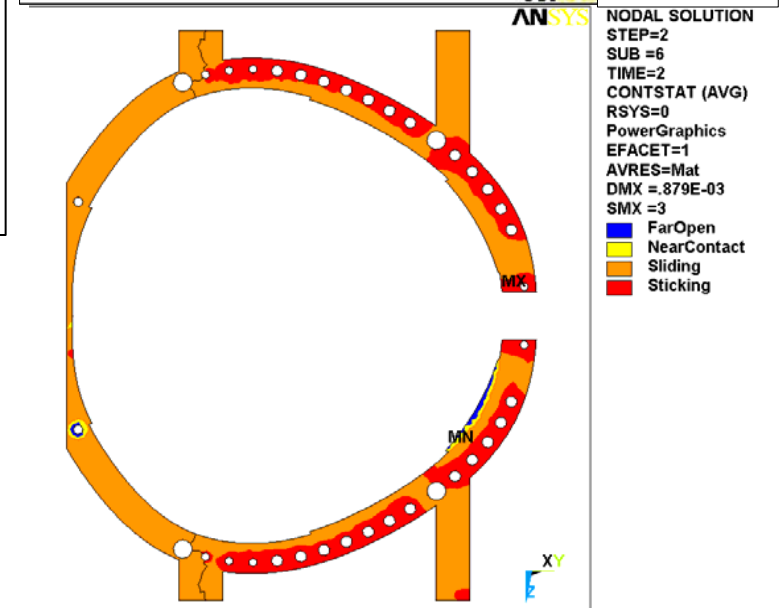
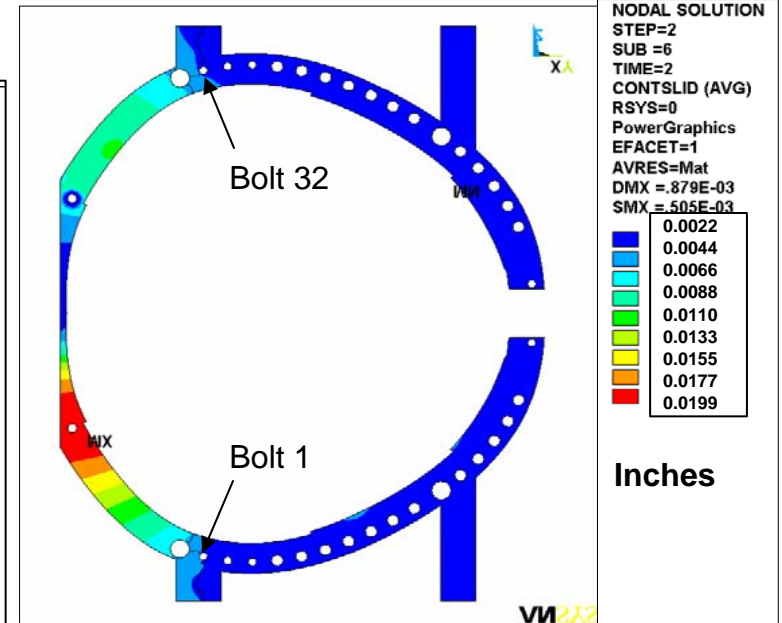
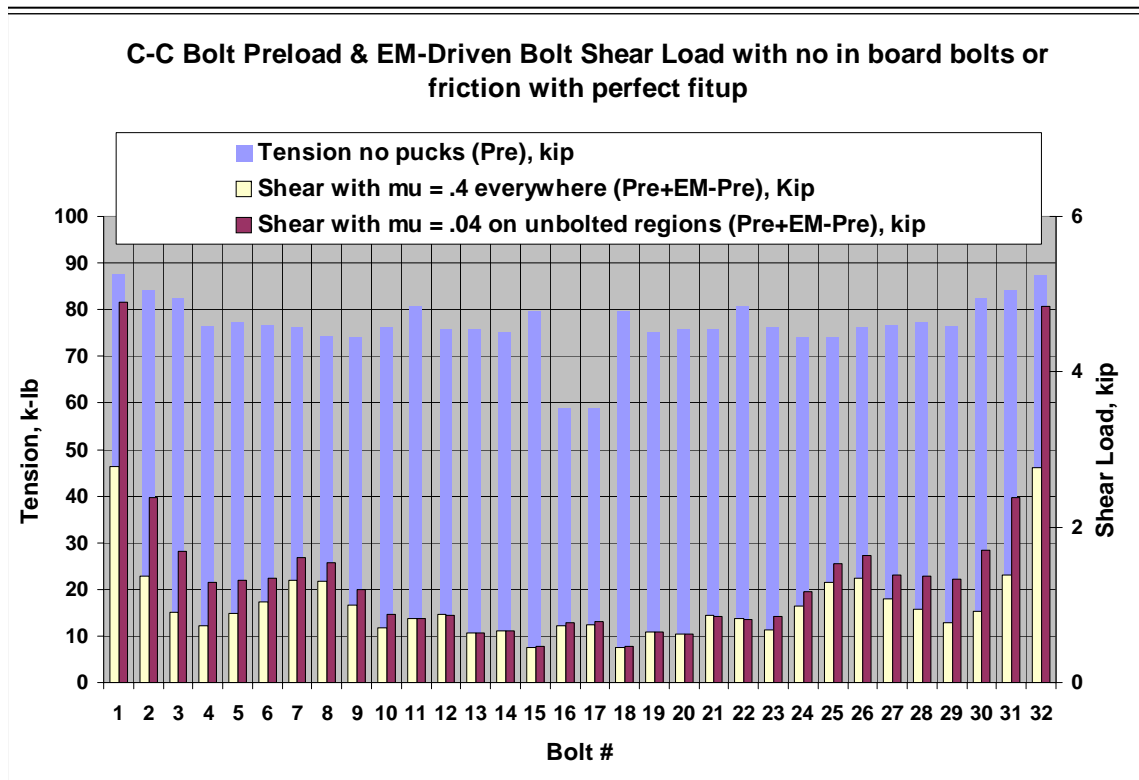
## ADDED 12 Inboard Bolts

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



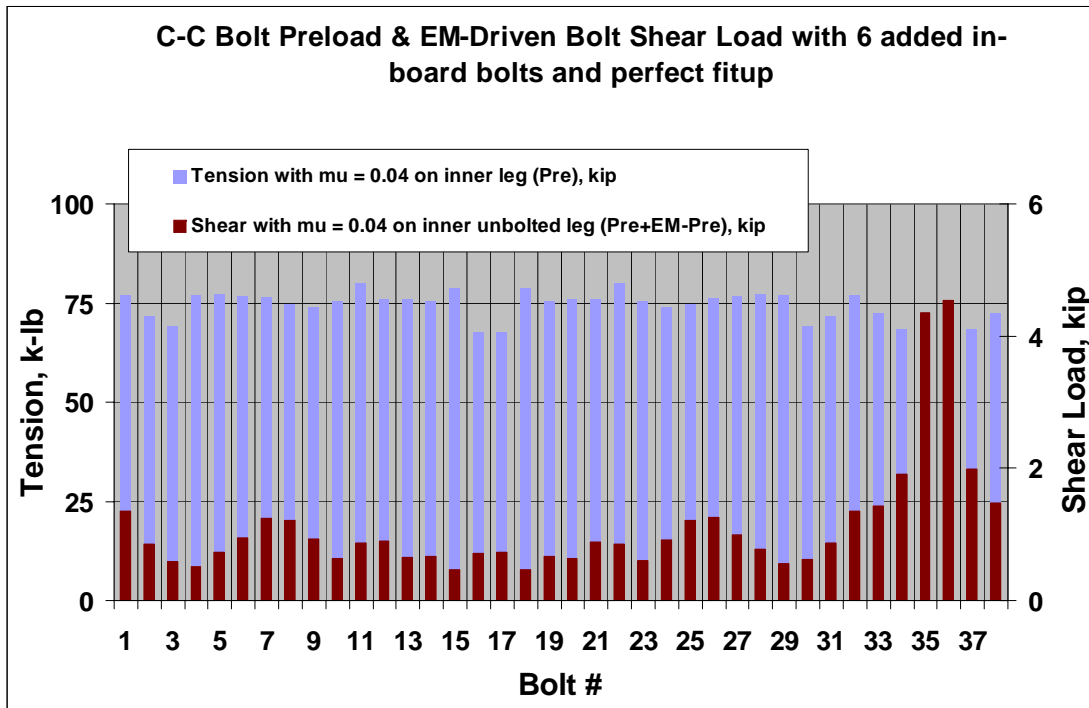
## No Inboard Bolt Friction

Frictionless In board leg

Peak Shear is 4.8 Kips

*Sliding is 19 mils*

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

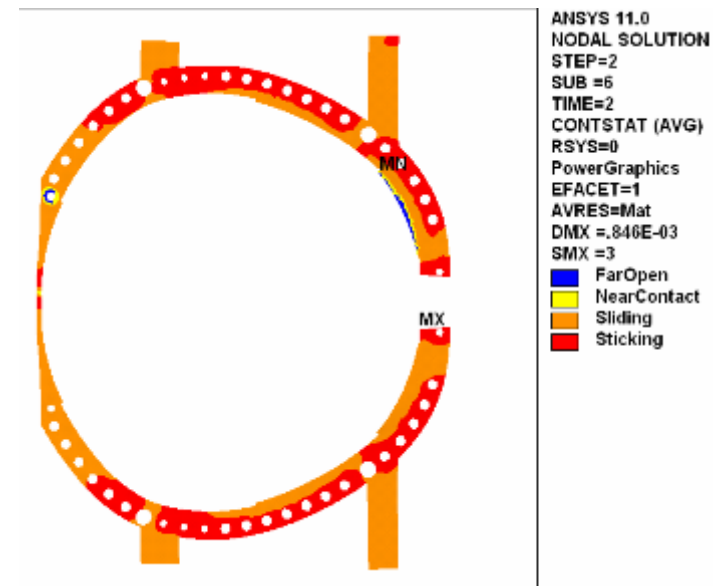
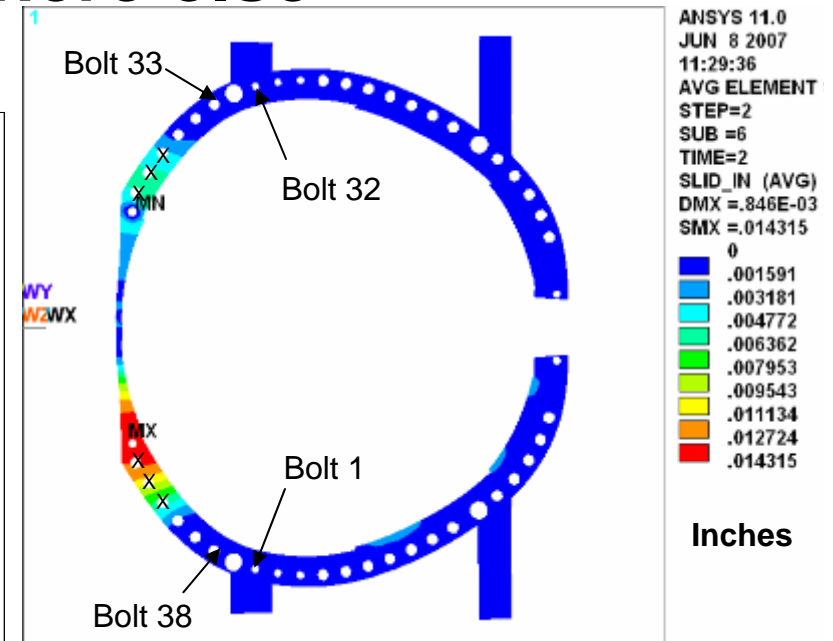


## ADDED 6 Inboard Bolts

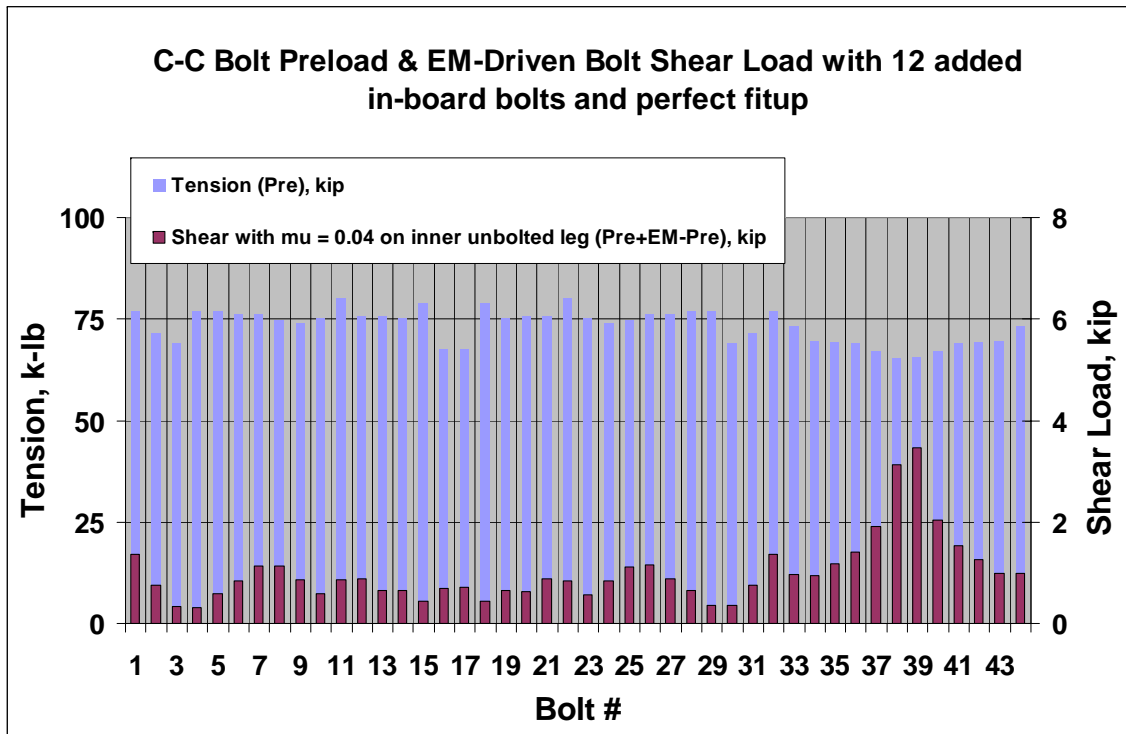
Frictionless In board leg

Peak Shear is 4.8 Kips

*Sliding is 14 mils*



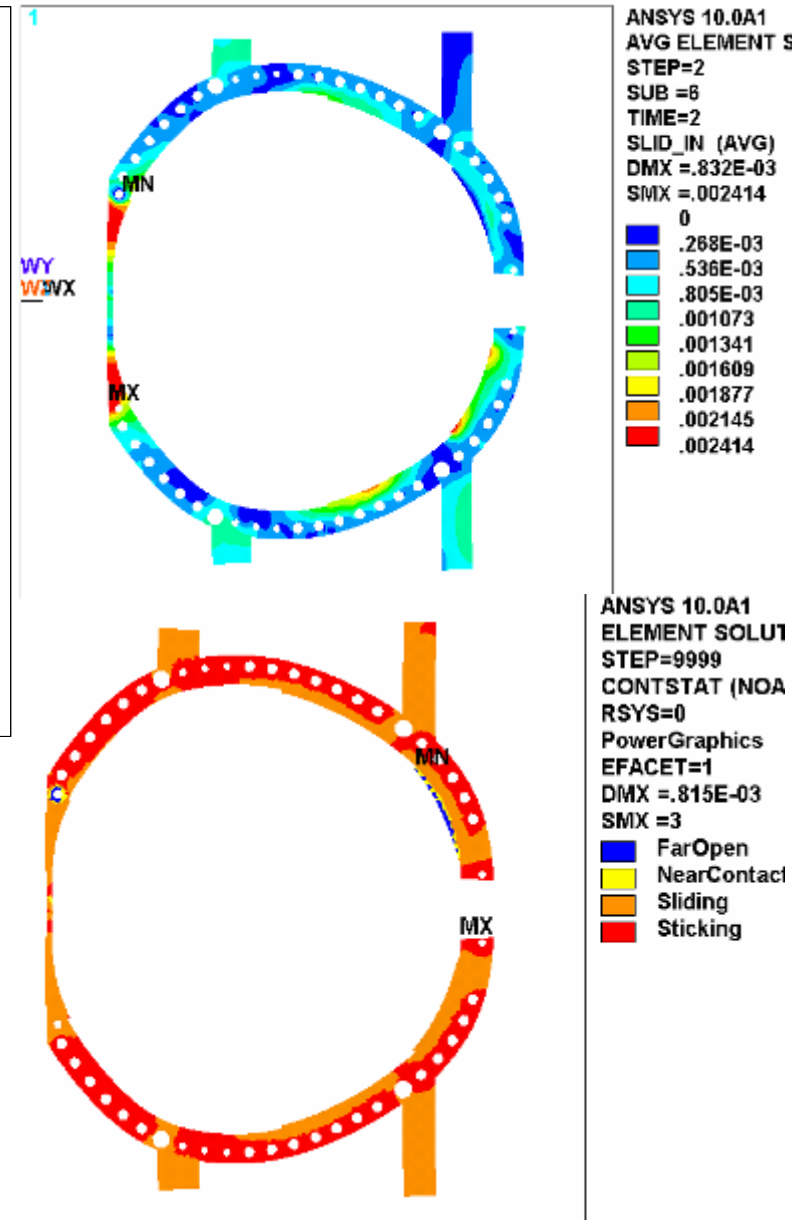
# Friction = 0.04 on Inner-leg region, mu = 0.4 everywhere else



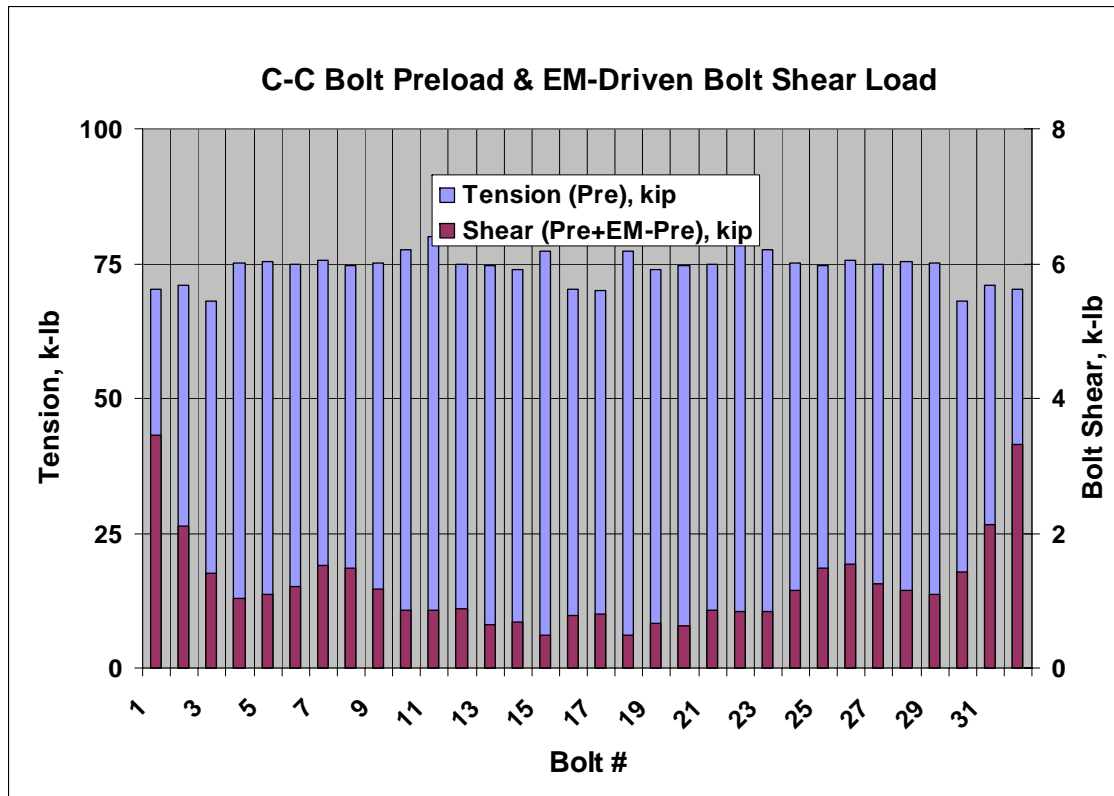
## ADDED 12 Inboard Bolts

Inner most bolts see 3.4 Kips

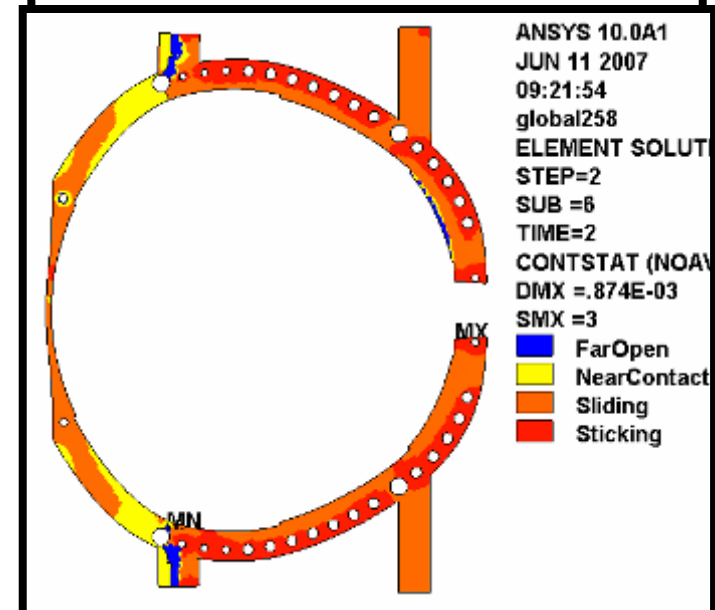
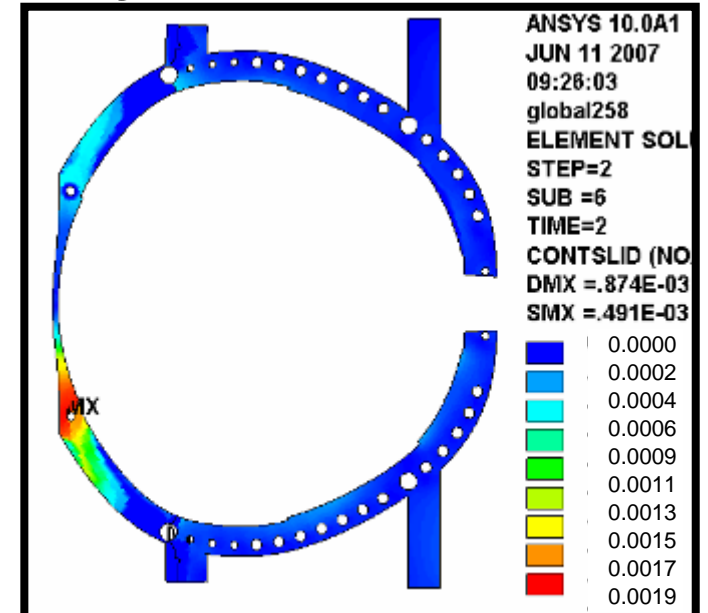
Sliding is less than 2.4 mils



**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

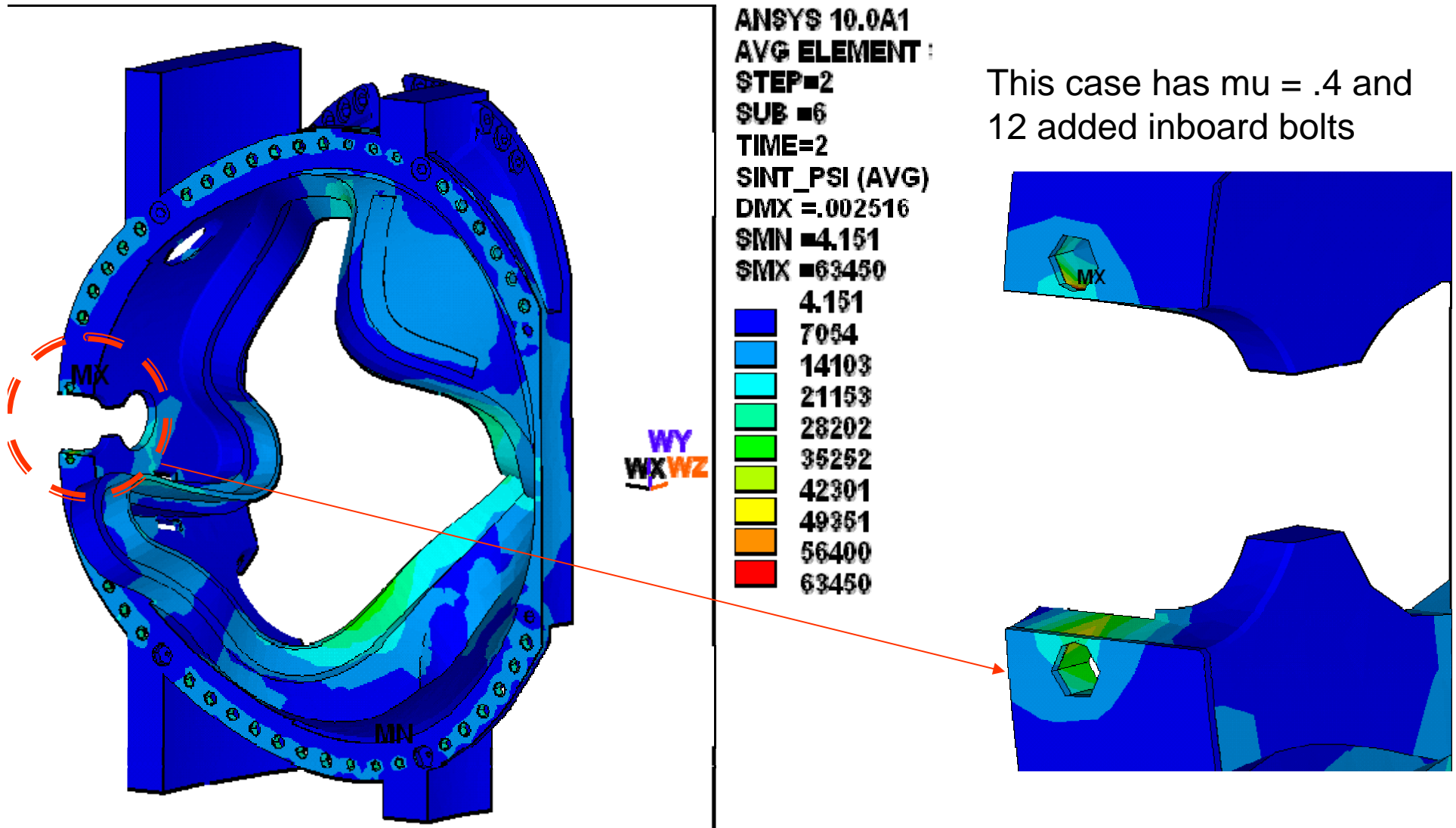
Inboard Friction	# of inboard bolts	Max sliding distance (in)	Max Shear Force (kips)
0.4	0	0.0065	2.8
0.4	6	0.0047	2.4
0.4	12	0.0011	2.7
0.04	0	0.0199	4.9
0.04	6	0.0143	4.5
0.04	12	0.0024	3.5
Imperfect Fit-up gap of .005" on unbolted region	0	0.0193*	3.3

\*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.

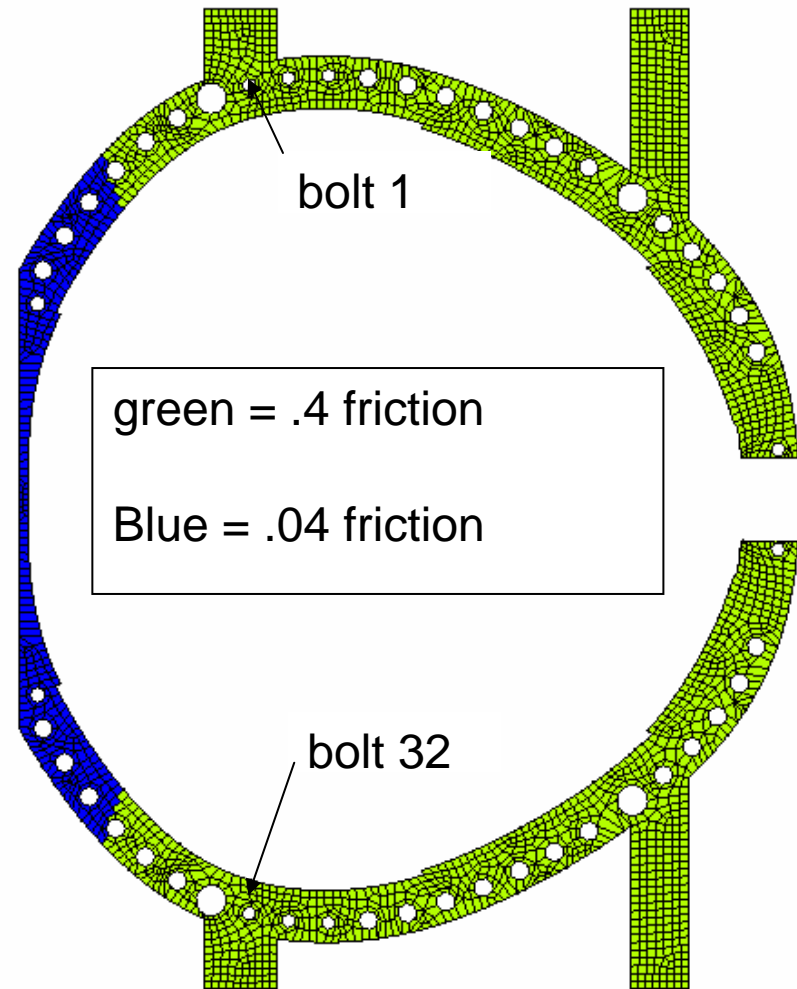
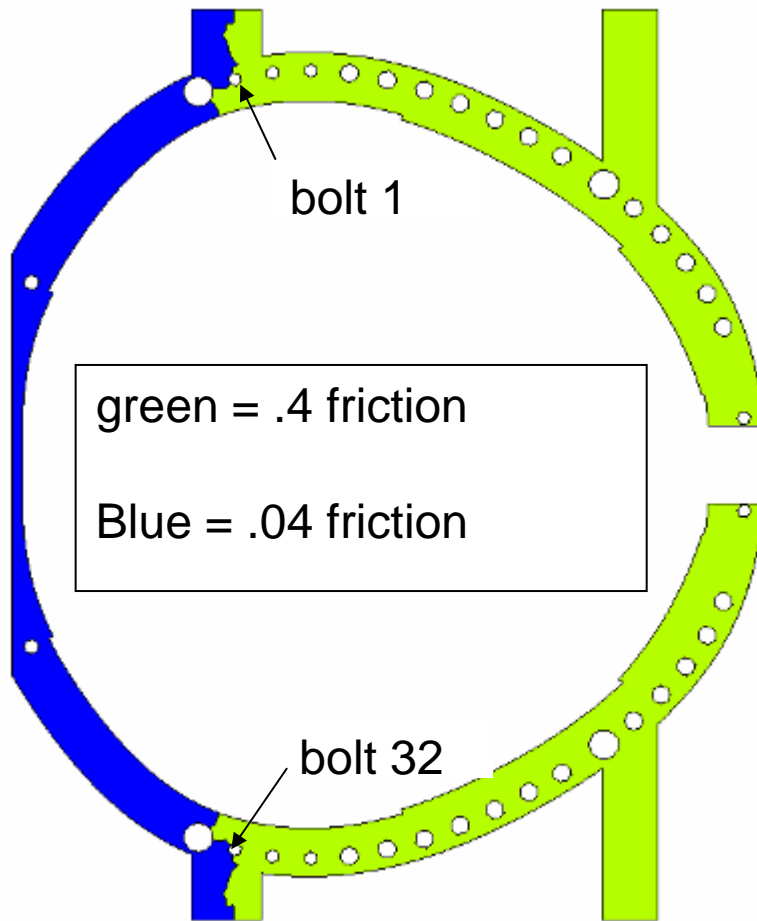


# Stress Intensity of flanges around bolts

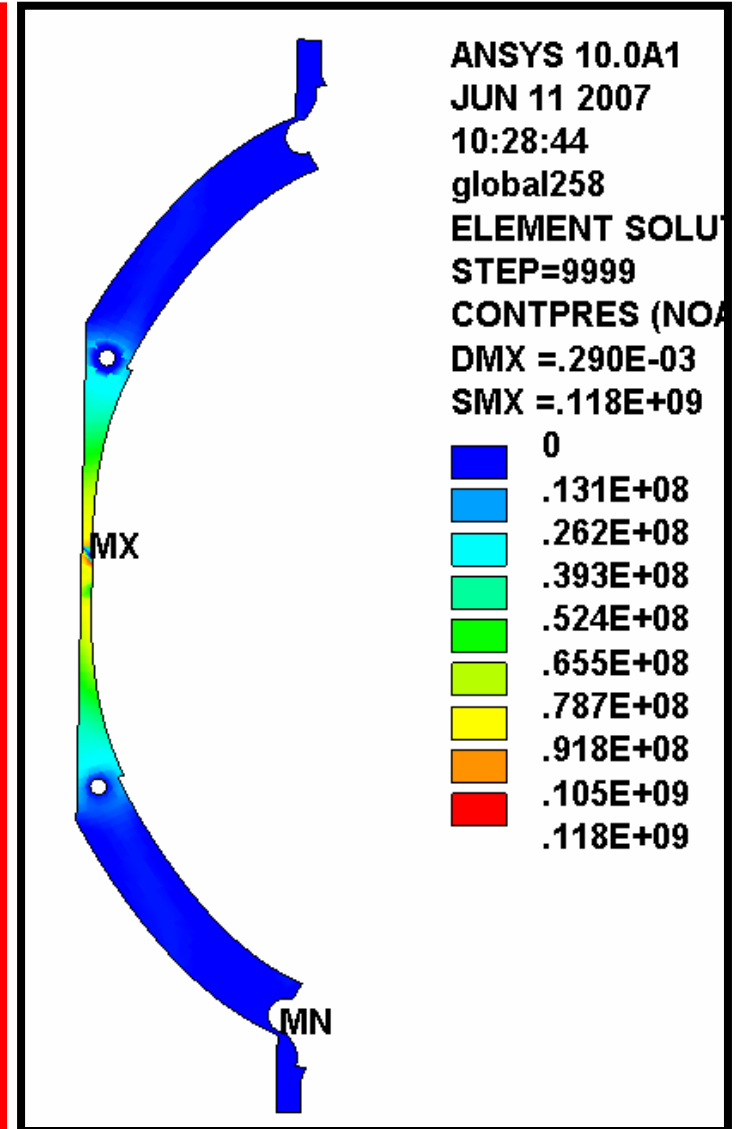
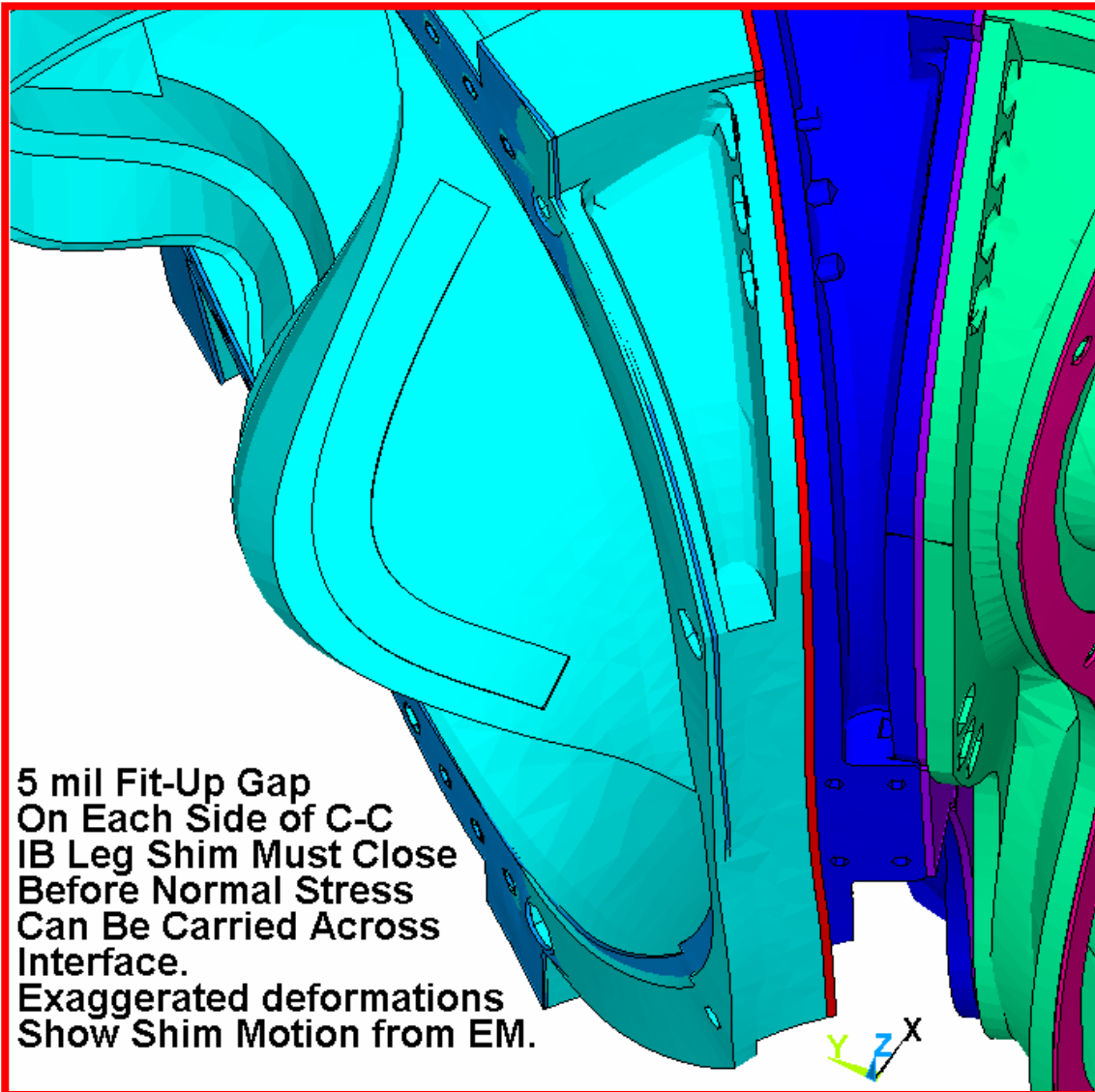


Tear out type stresses (peak 64 ksi, average approx 48 ksi) on this flange are a bit bothersome, may want to consider leaving these two bolts out.

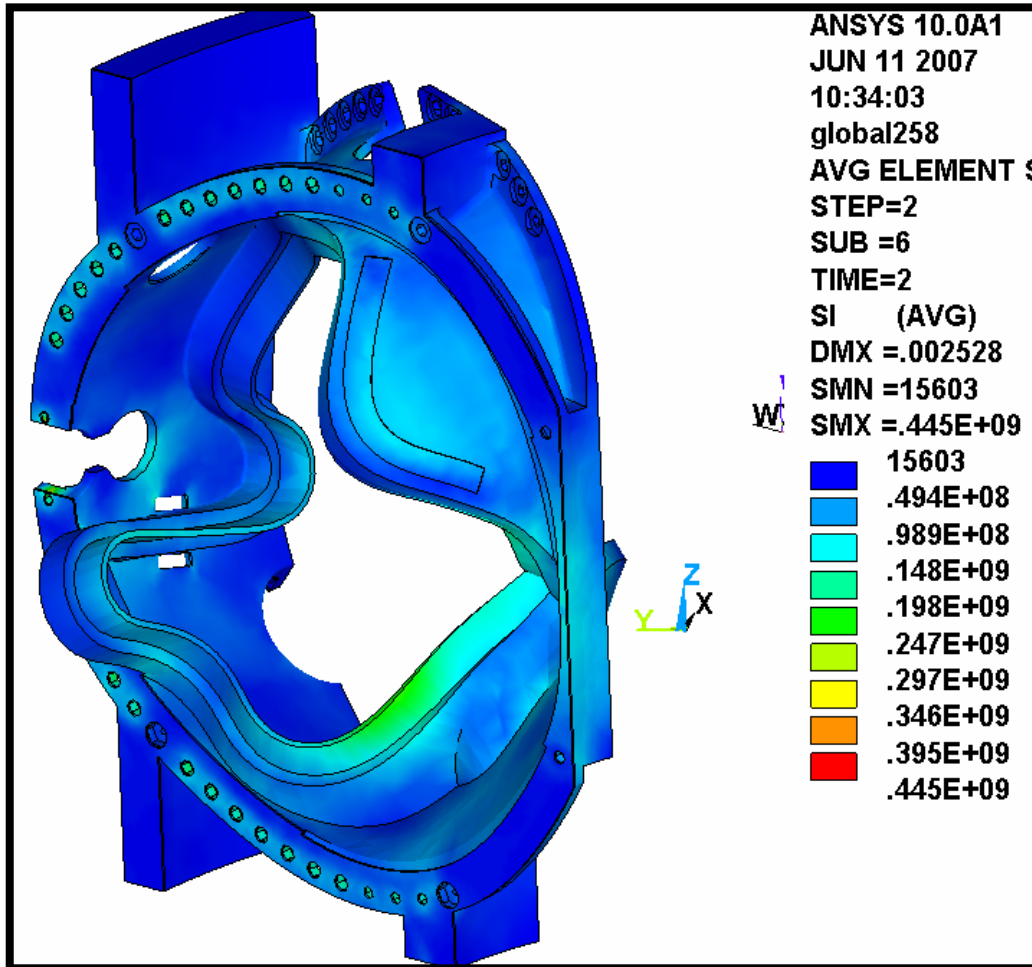
# Contact Sliding regions



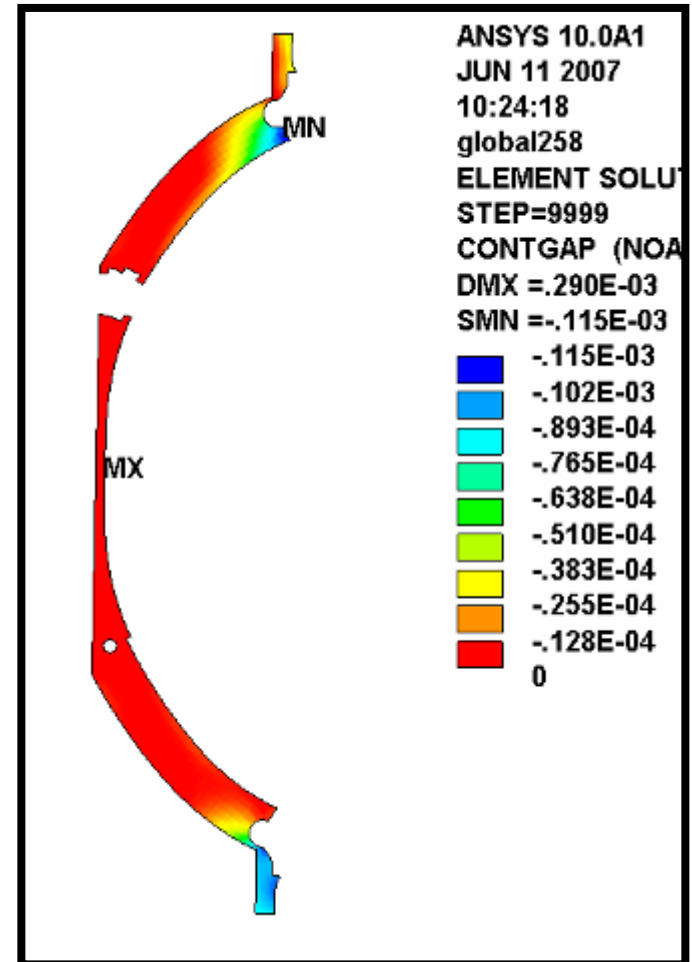
# Slides from imperfect fit-up run



# 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.