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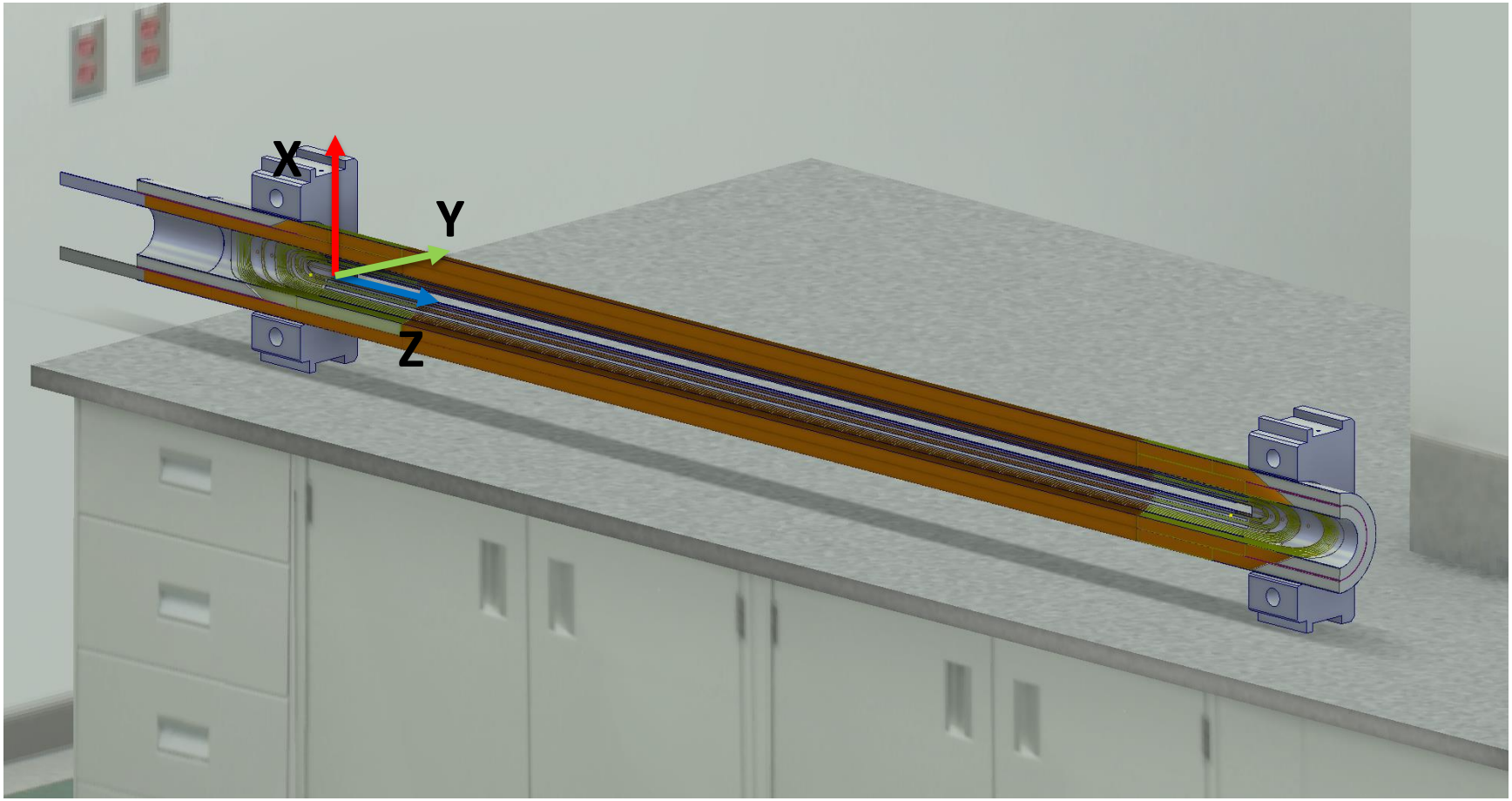
TE-MSC

Coil measurements – shimming plan

Measurement in the assembly

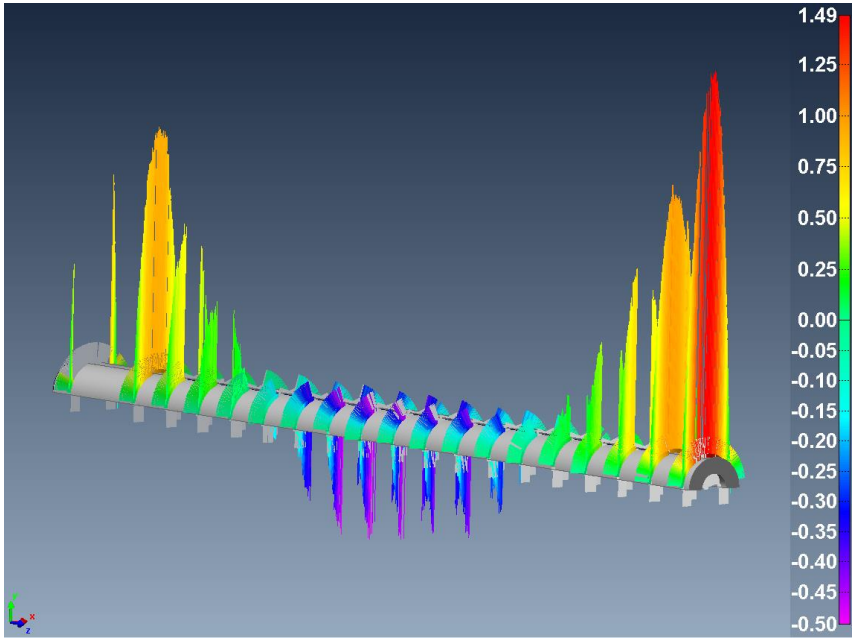
- 3d-measurement arm
  - Tactile ball probe (accuracy 5µm; precision 15µm)
  - Laser scanner (precision 40µm)
- PolyWorks 3d-metrology software

Measurements on coil 108



Measurements on coil 108

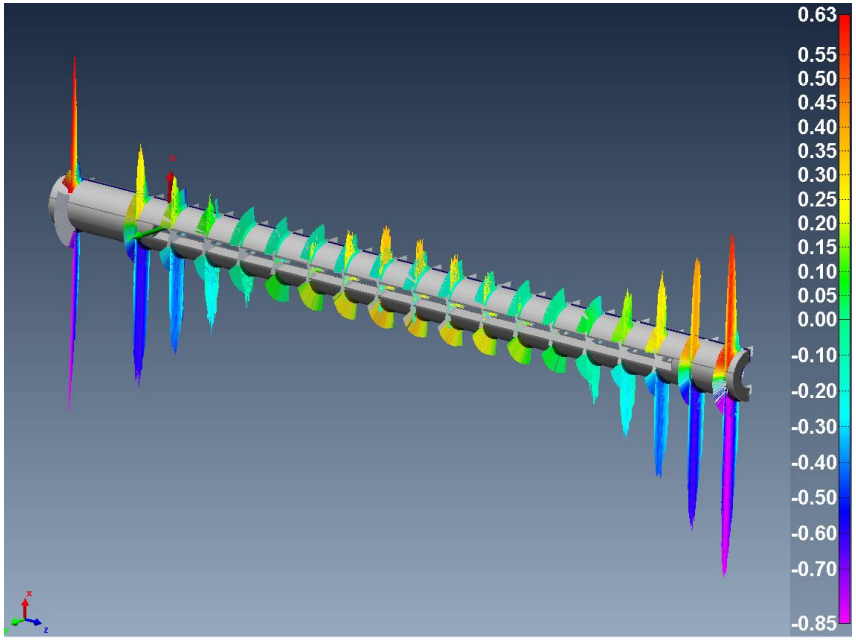
Deviation in Y



- Gravity is working in X-axis
- Displacement in Y is the coils free form
- Displacement in X is due to bending from the fixing points

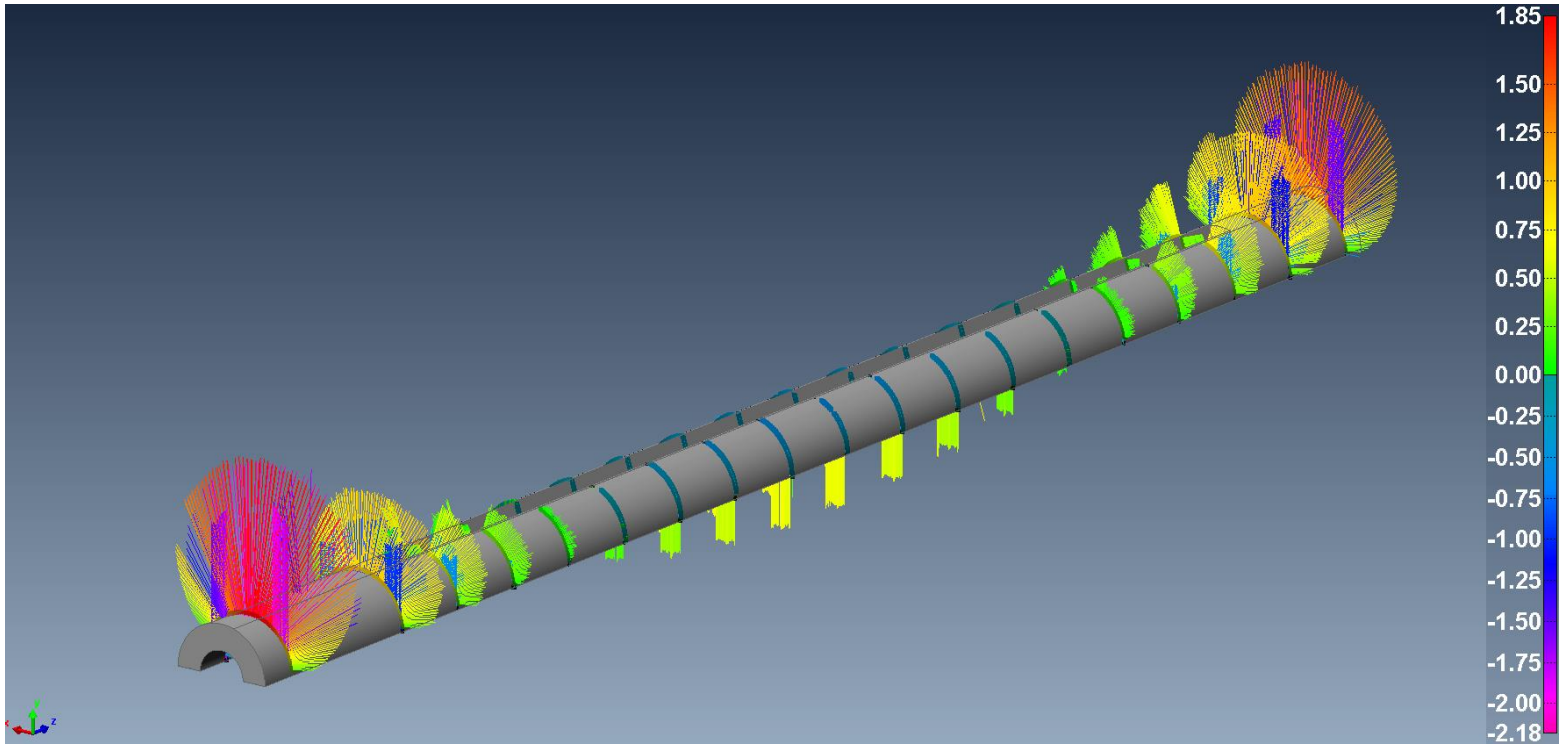
Measurements on coil 108

Deviation in X



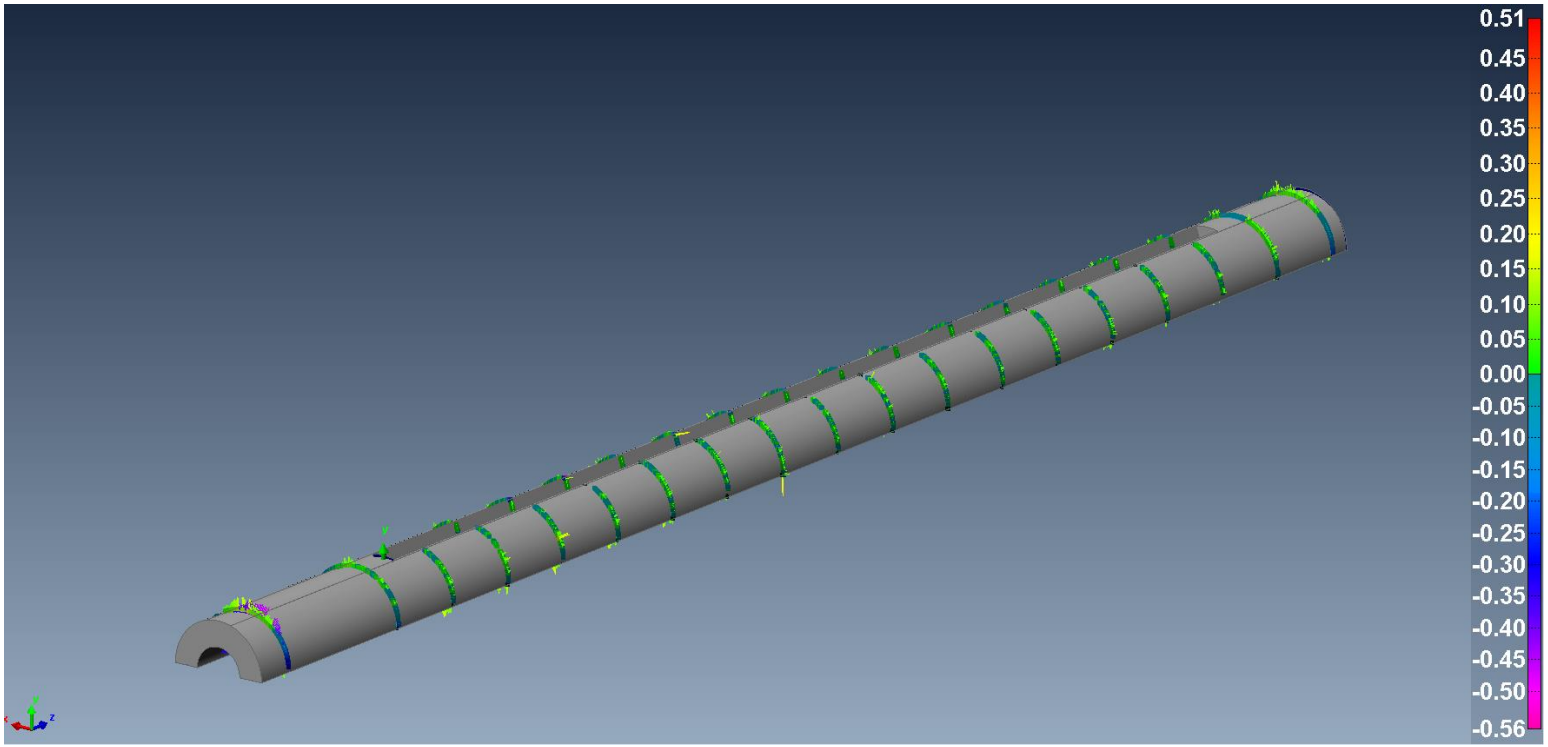
- Gravity is working in X-axis
- Displacement in Y is the coils free form
- Displacement in X is due to bending from the fixing points

Measurements on coil 108



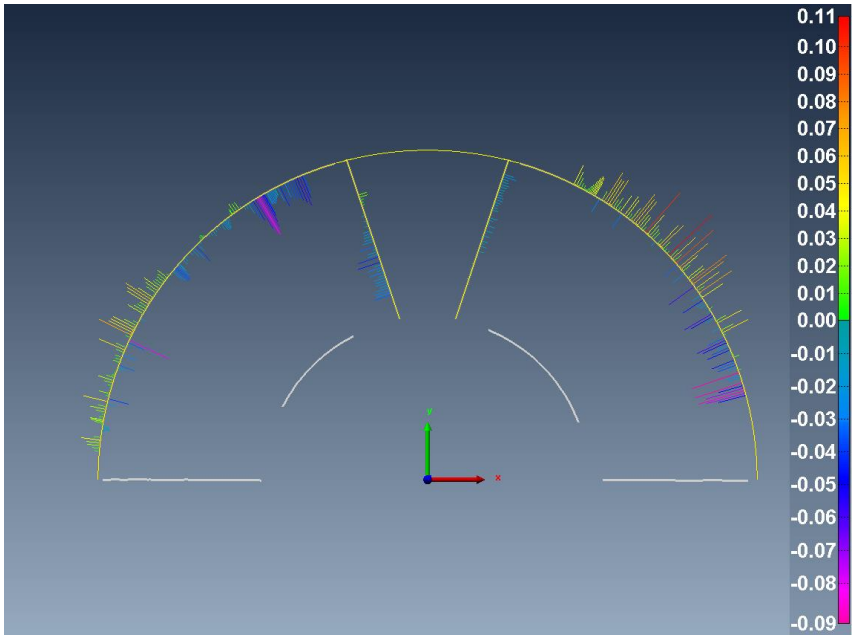
- Cross sections 100mm steps
- Best-fit with whole point cloud

Measurements on coil 108



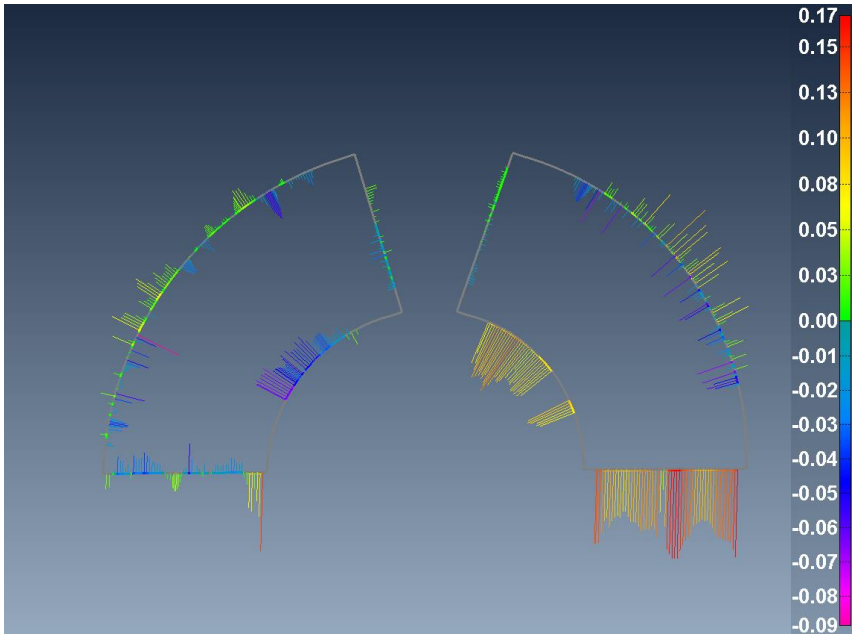
- Each cross section is aligned individually
- With these cross section the shimming plan can be determined

Alignment of the cross sections



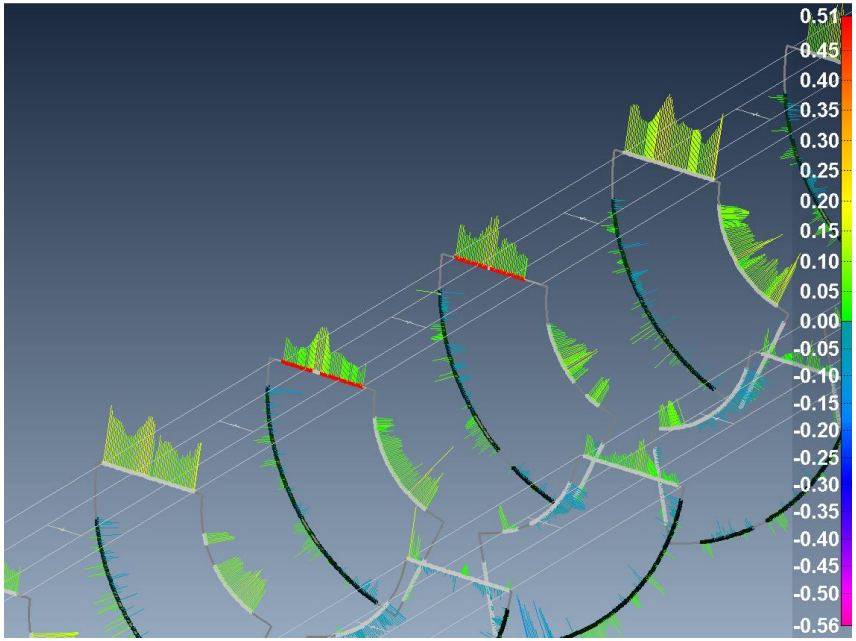
- Best fit on loading plate and outer diameter
- Left and right part are individually aligned
- Fit quality criteria all cs:
  - Outer diameter
    - Stdev < 0.05mm
    - Dev. min/max < 0.25mm
  - Loading plate
    - Stdev < 0.01mm
    - Dev. min/max < 0.05mm

Alignment of the cross sections



- Final result
  - Noise on the outer diameter is from the surface topology of the coil
  - Inner diameter is off centre
  - Midplanes in different position
- How to quantify this misplacement of the midplanes?

Measurements – extracting quantifiable values

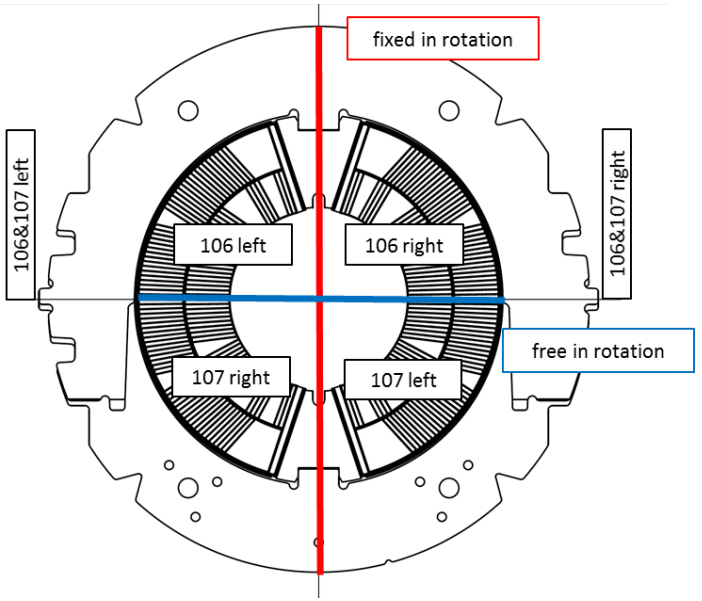


- Best fitting squares on the midplane
  - Every 10cm over the whole length
  - Rejecting 5% outliers of the points
- Position of these squares represents the oversize of the midplane

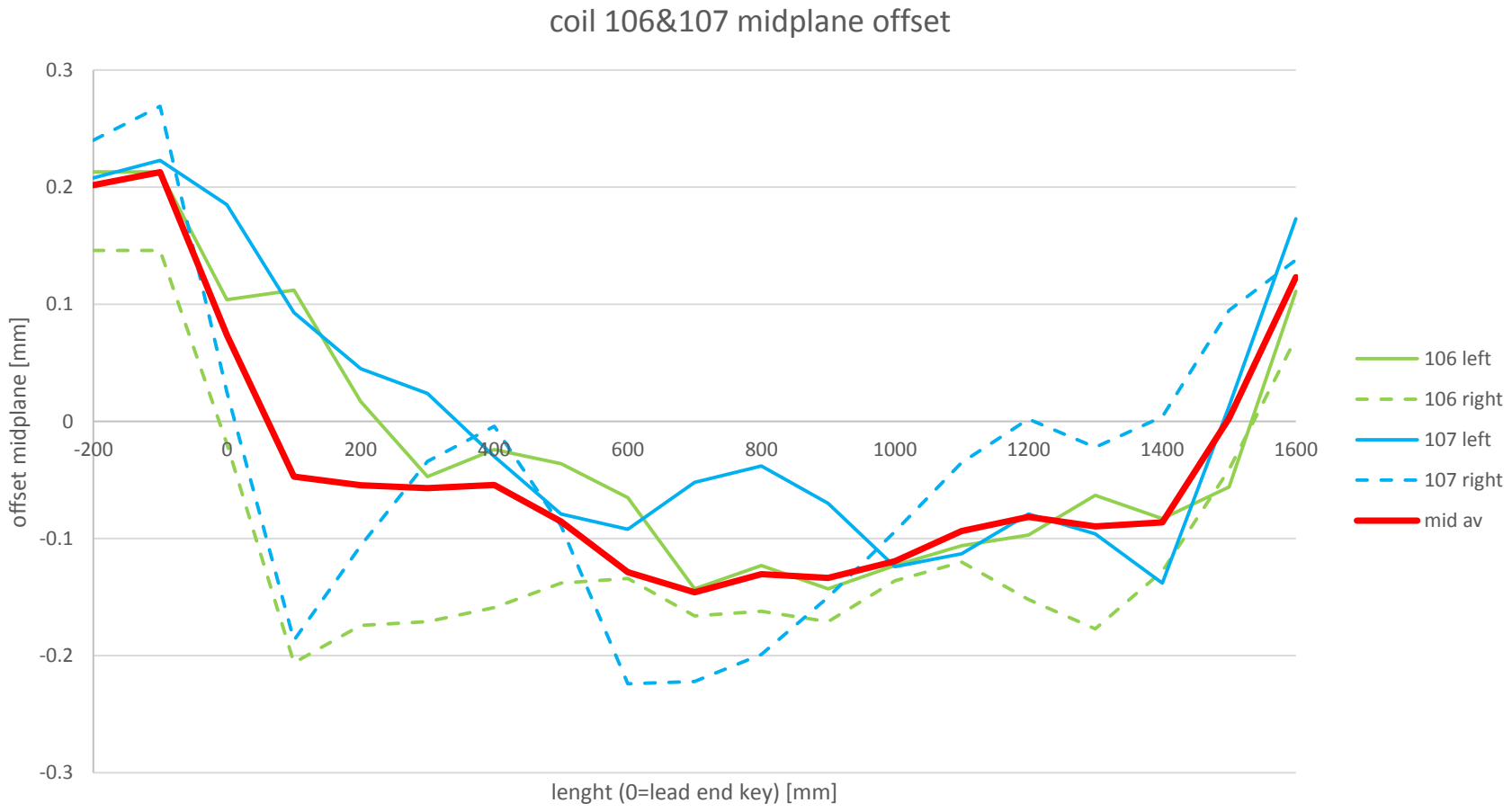
Using quantifiable values

z-axis	106 + left	z-axis	106 - right	z-axis	107 + left	z-axis	107 - right
-200	0.213	-200	0.146	-200	0.208	-200	0.24
-100	0.213	-100	0.146	-100	0.223	-100	0.269
0	0.104	0	-0.019	0	0.185	0	0.025
100	0.112	100	-0.206	100	0.093	100	-0.187
200	0.017	200	-0.174	200	0.045	200	-0.106
300	-0.047	300	-0.171	300	0.024	300	-0.034
400	-0.024	400	-0.159	400	-0.03	400	-0.004
500	-0.036	500	-0.138	500	-0.079	500	-0.089
600	-0.065	600	-0.134	600	-0.092	600	-0.224
700	-0.143	700	-0.166	700	-0.052	700	-0.222
800	-0.123	800	-0.162	800	-0.038	800	-0.199
900	-0.143	900	-0.171	900	-0.07	900	-0.15
1000	-0.123	1000	-0.136	1000	-0.124	1000	-0.094
1100	-0.106	1100	-0.12	1100	-0.113	1100	-0.035
1200	-0.097	1200	-0.152	1200	-0.079	1200	0.002
1300	-0.063	1300	-0.177	1300	-0.096	1300	-0.022
1400	-0.083	1400	-0.128	1400	-0.138	1400	0.004
1500	-0.056	1500	-0.041	1500	0.013	1500	0.095
1600	0.111	1600	0.071	1600	0.173	1600	0.138

- Positive values represent a to small coil
- When the coils get paired 106 left will be in contact with 107 right



Using quantifiable values



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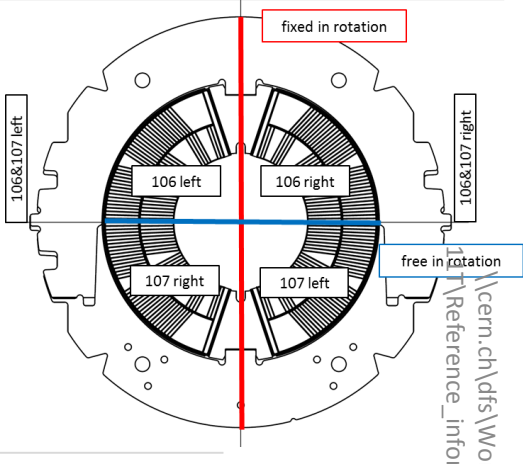
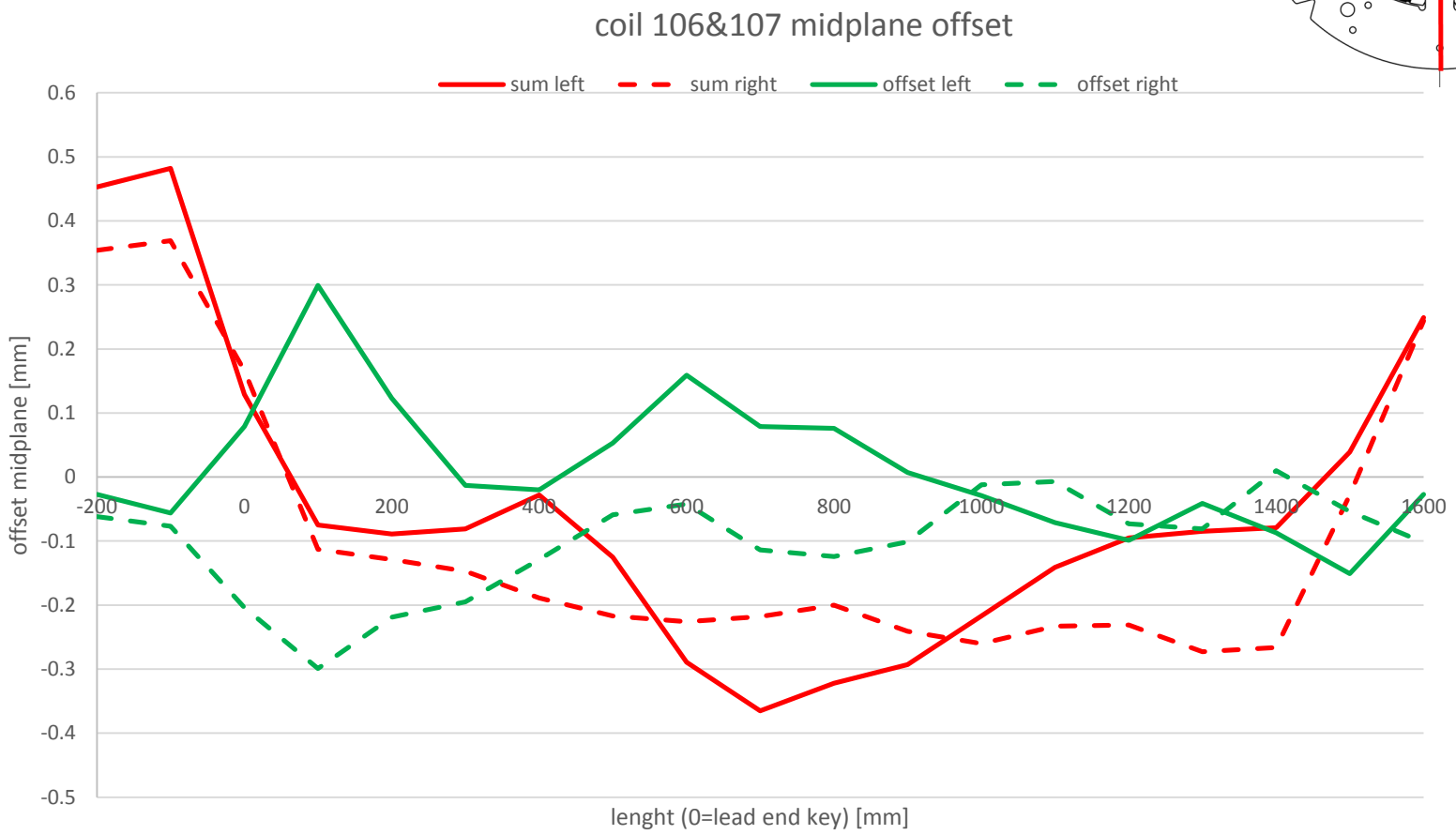
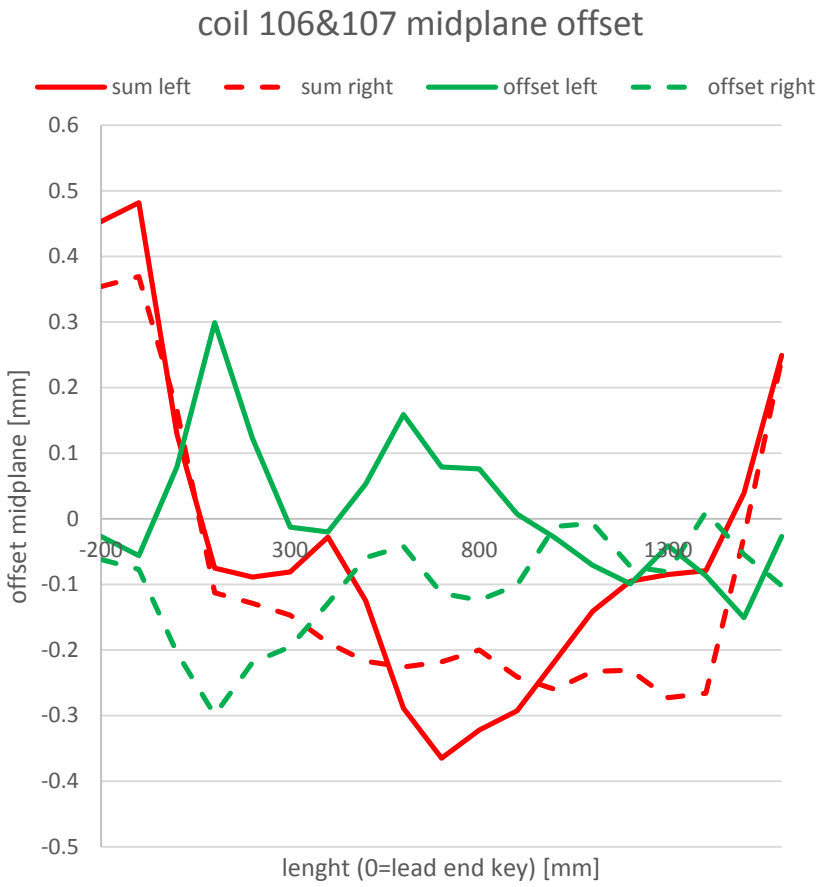
Using quantifiable values





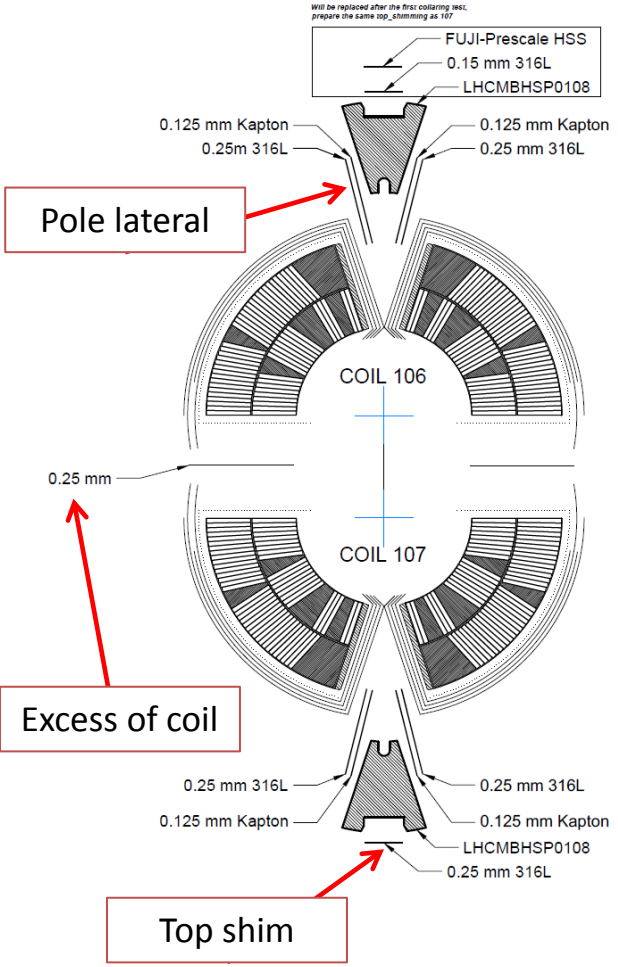
Using quantifiable values



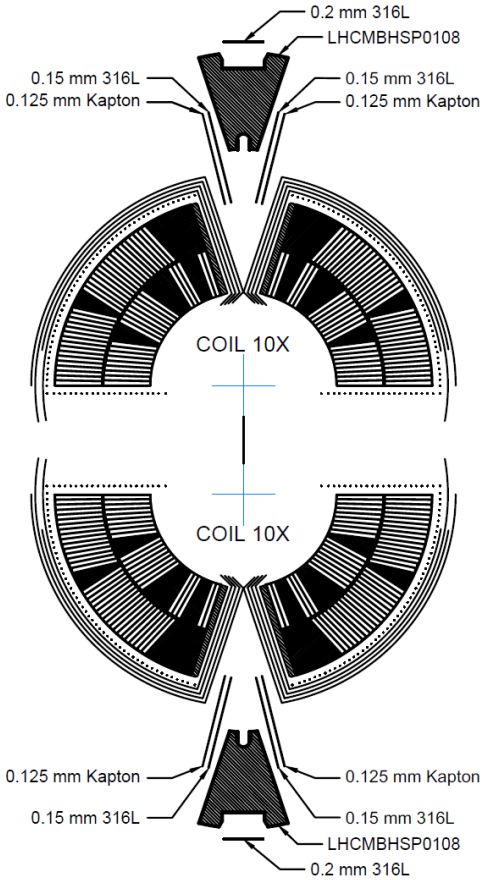
- The sums on both sides are similar over the length
- Offset might be critical for field quality

Shimming plan

MBHSP101



No pre stress



- We use the data from the 300mm in the middle of the coil to determine our shimming
- For MBHSP101 it is 0.25mm, on average, to much on the midplane
- The shims were adapted accordingly to MBHSM101

coil excess+ pole lateral+ pole top*tan(18.387°)= azimuthal displacement

no pre stress:
0.15+0.125+0.2*tan(18.387°)= 0.3414mm

MBHSP101:
0.25/2+0.25+0.125+0.25*tan(18.387°)= 0.5831mm

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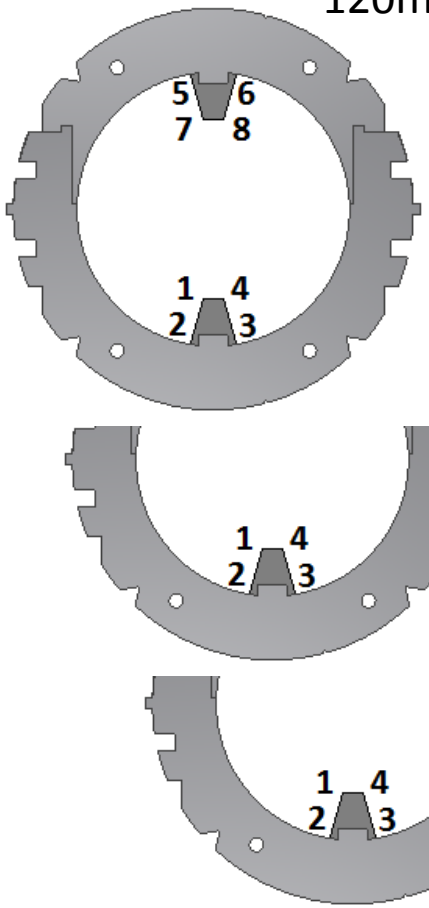
Assembly and FEM comparison

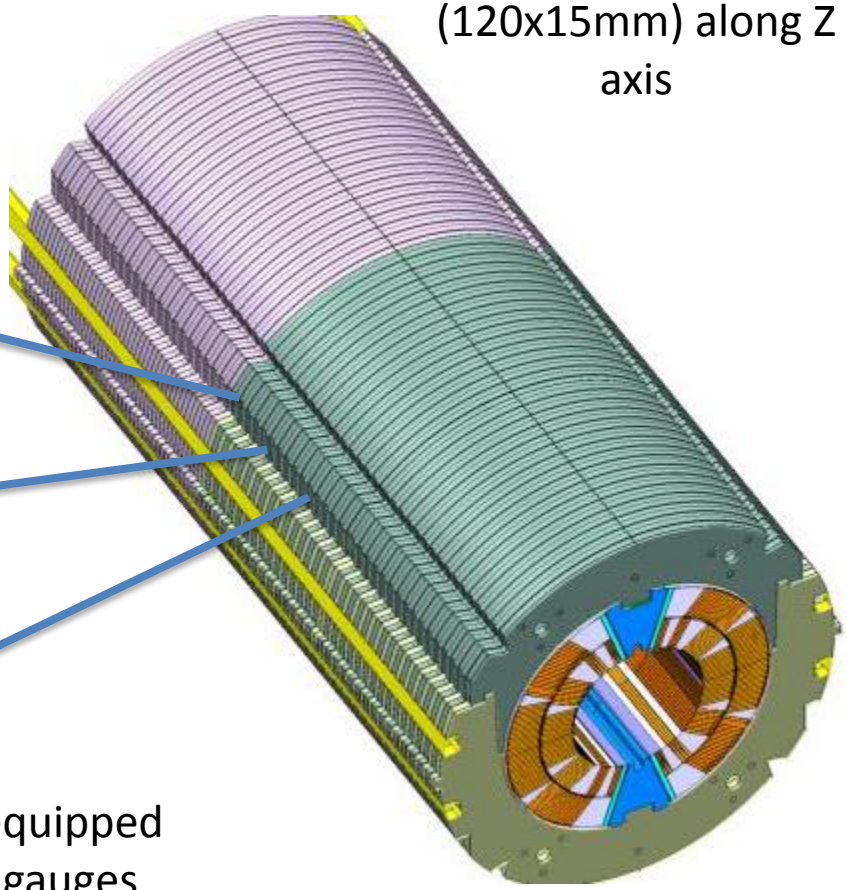
Instrumentation MBHSP101

6 Collars instrumented for 120mm length



Both side equipped with strain gauges

8 Capacitive gauges (120x15mm) along Z axis



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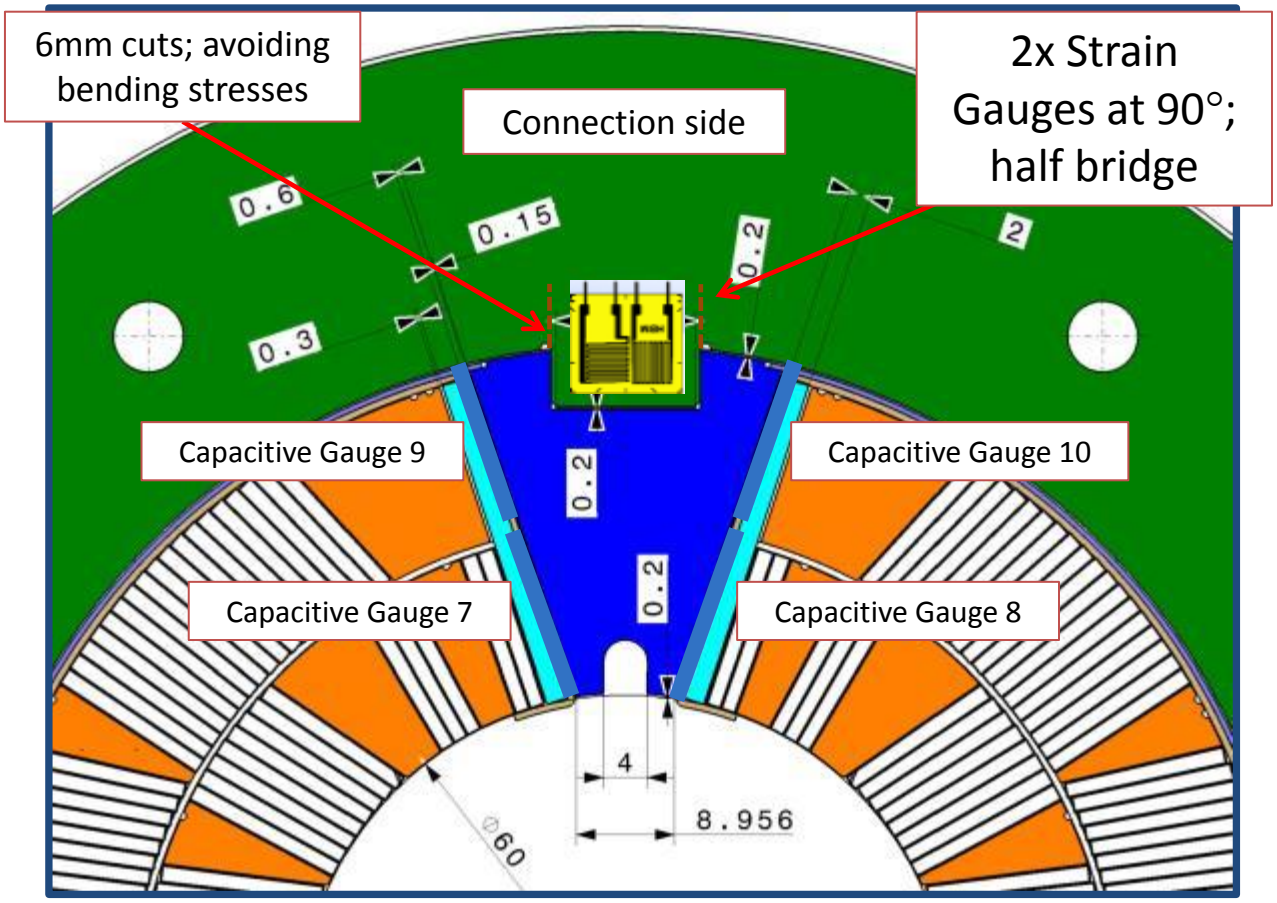
Instrumentation MBHSP101



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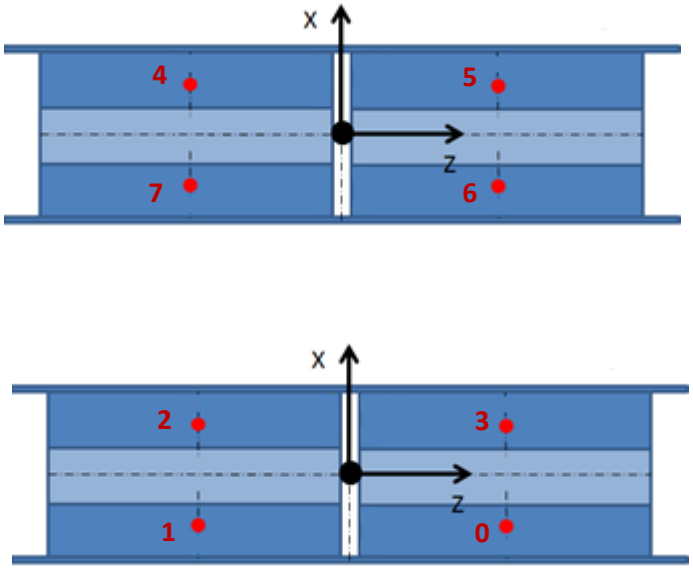
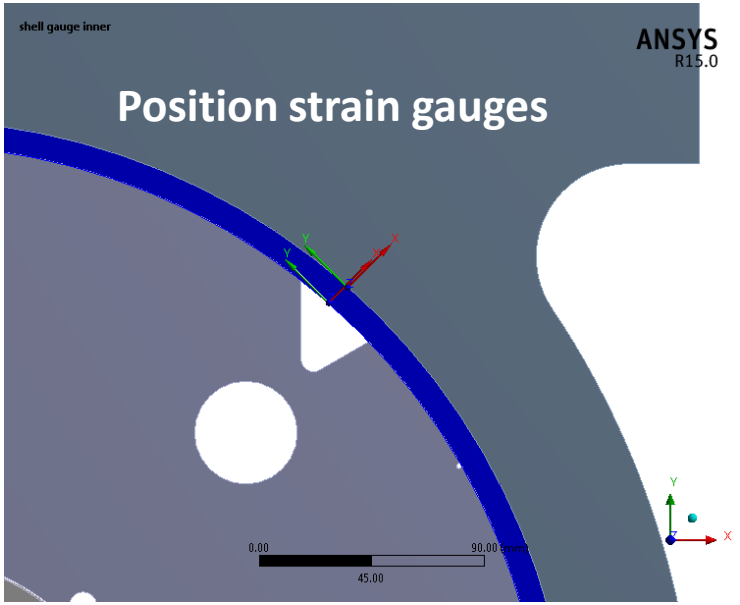
Instrumentation MBHSP101

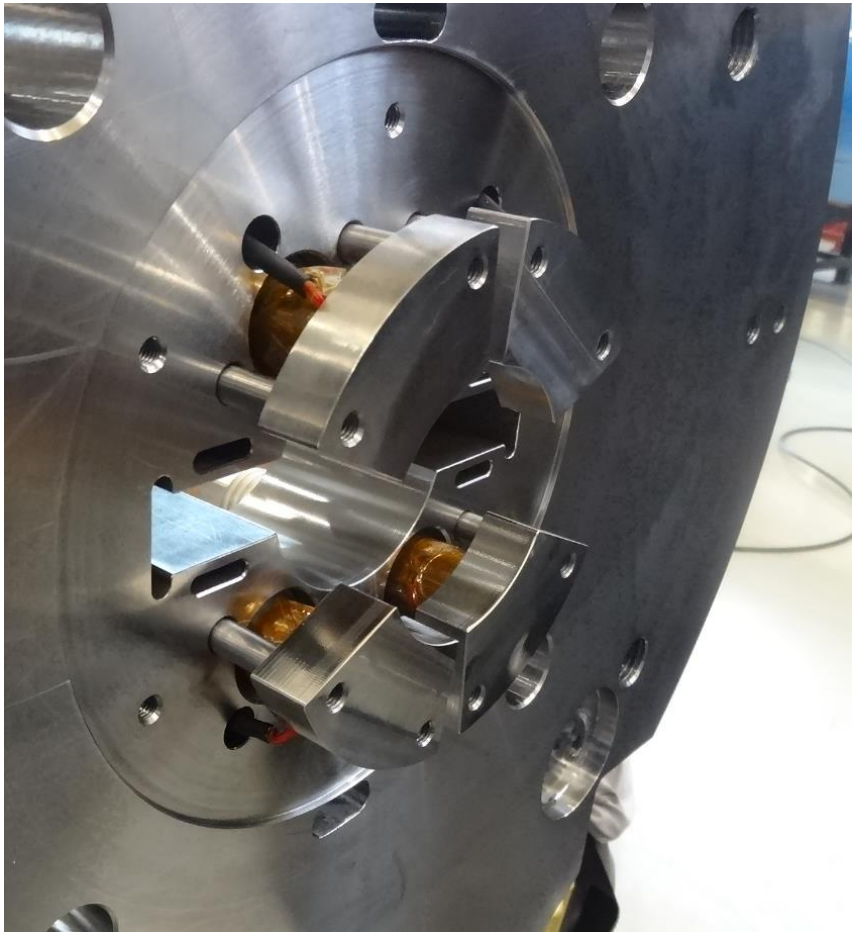


Shell:

- 8 pairs of strain gauges on the inner and outer shell
- Quarter bridges with compensator



Instrumentation MBHSP101

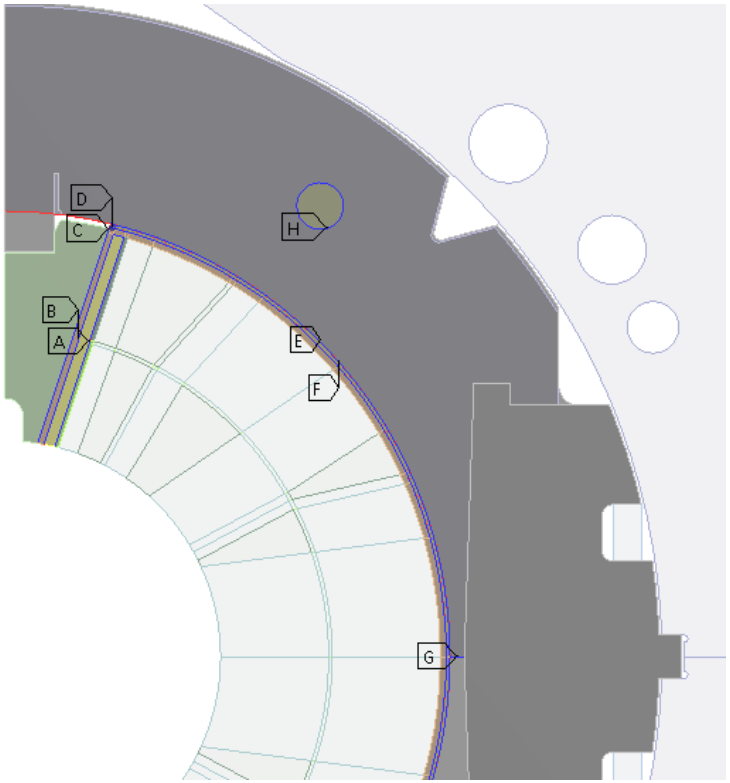


Heads:

- Instrumented bullets pressing on the loading plates
- Bullets are compressed by screws
- Instrumentation is on the bullets

ANSYS Setup - contacts

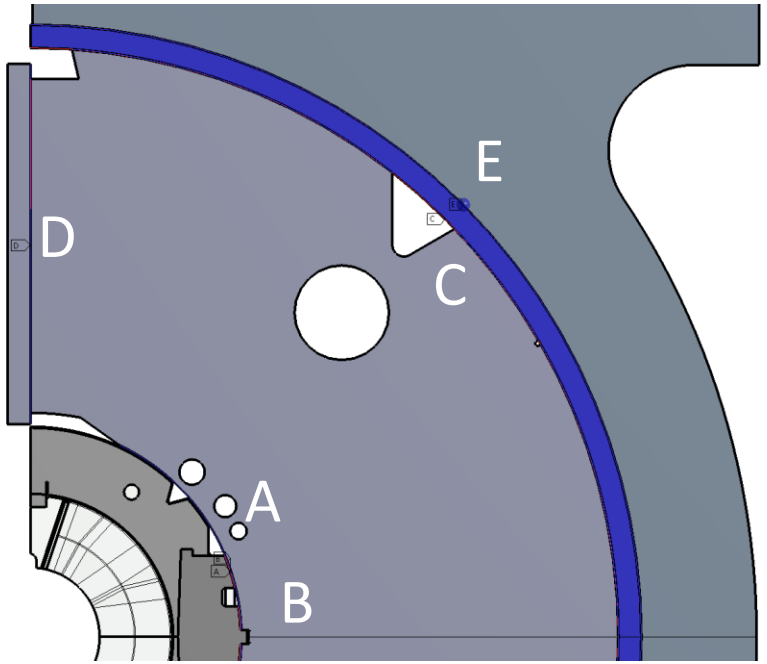
- A Bonded - 1001_1002_C Loading plate - Coil To 1001_1002_T Loading plate - Coil
- B Bonded - 1003_1004_C Loading plate - Ground insulation To 1003_1004_T Loading plate - Ground insulation
- C Frictionless - 1007_1008_C Pole Shim - Central post To 1007_1008_T Pole Shim - Central post
- D Frictionless - 1009_1010_C Insulation - Collaring shoe To 1009_1010_T Insulation - Collaring shoe
- E Frictionless - 1011_1012_C Collar pack 1 - Collaring Shoe To 1011_1012_T Collar pack 1 - Collaring Shoe
- F Frictionless - 1013_1014_C Collar pack 2 - Collaring shoe To 1013_1014_T Collar pack 2 - Collaring shoe
- G Frictionless - 1019_1020_C Collars long short 1 To 1019_1020_T Collars long short 1
- H Bonded - 1031_1032_C Collar long weld To 1033_1034_T Collar Long weld



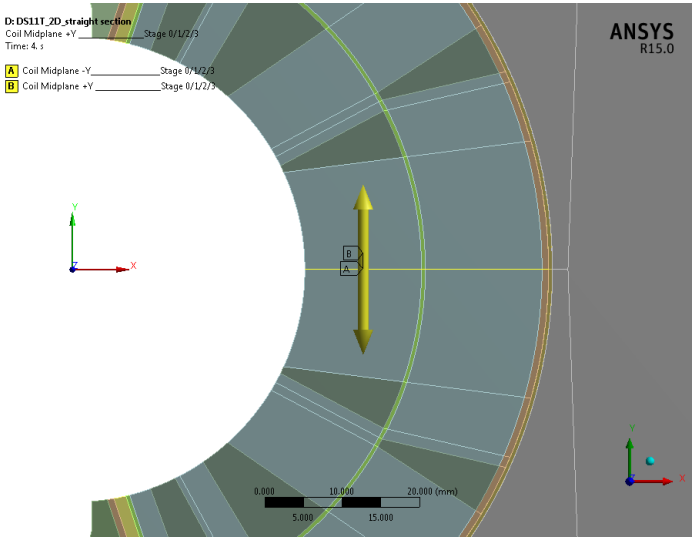
coil, wedges – bonded

ANSYS Setup - contacts

- A Frictionless - Long Collar To Multiple
- B Frictionless - Long Collar To Multiple
- C Frictionless - 1069_1070_C Shell Yoke To 1069_1070_T Shell Yoke
- D Frictionless - 1071_1072_C Yoke Yoke To 1071_1072_T Yoke Yoke
- E Frictionless - 1073_1074_C Cradel - Shell To 1073_1074_T Cradel - Shell

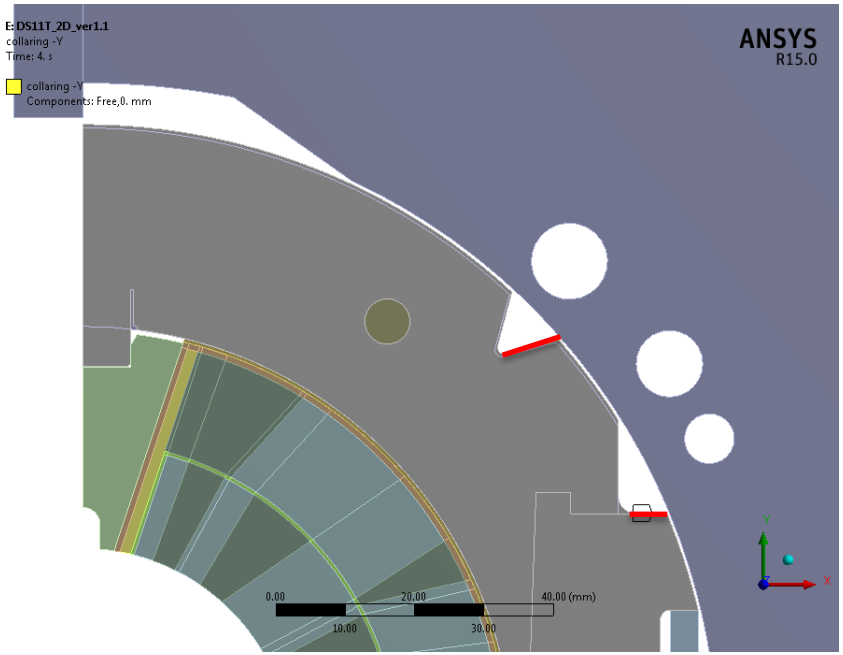


ANSYS Setup - shimming_step 1



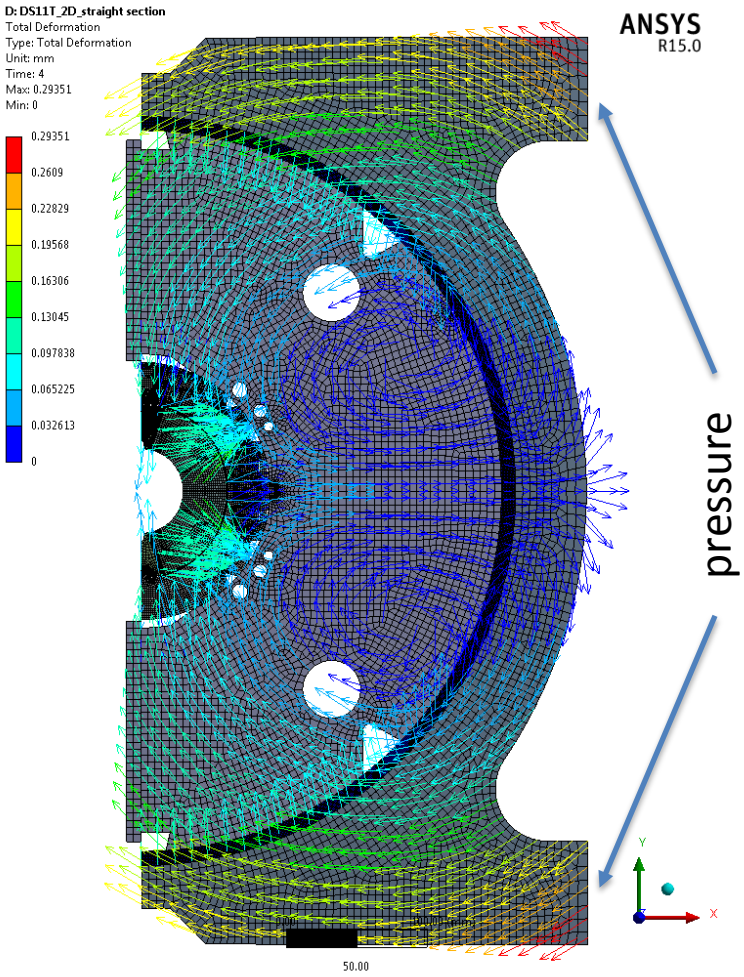
- Before the first step the model is stress free
- The midplane gets displaced to simulate the geometrical excess
- Contacts between loading_pole and collar/loading_plate increase according to shimming plan

ANSYS Setup - collaring_step 2

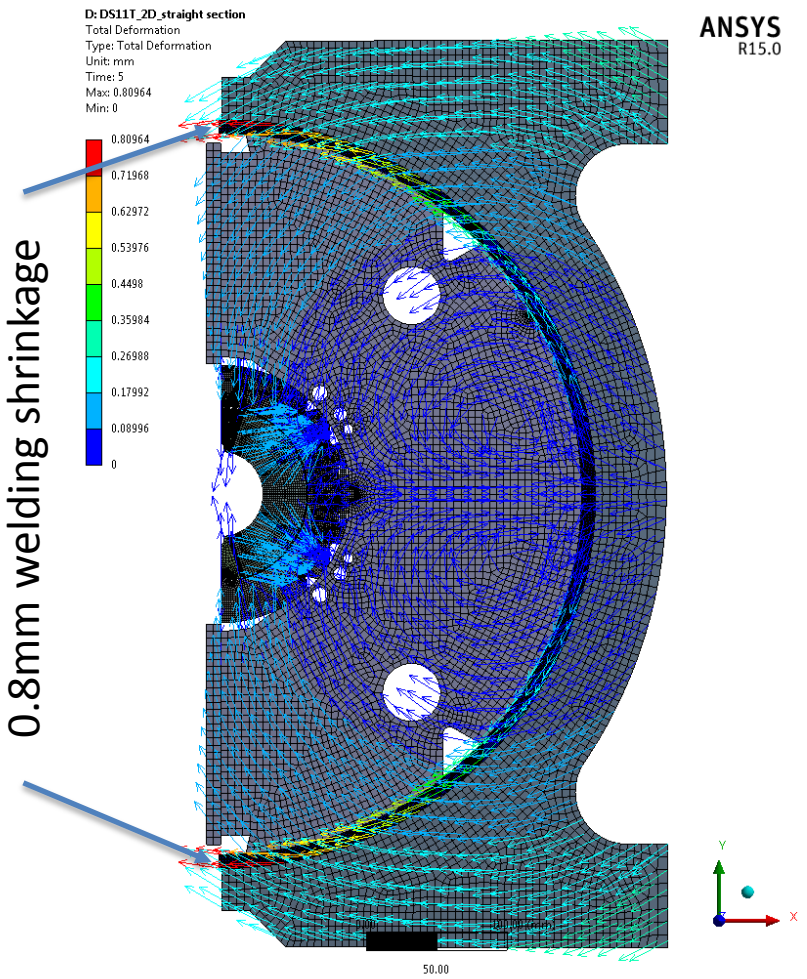


- Displacement of 0.05mm per collar towards the midplane
- Free in X-axis

ANSYS Setup - welding_step 3-6

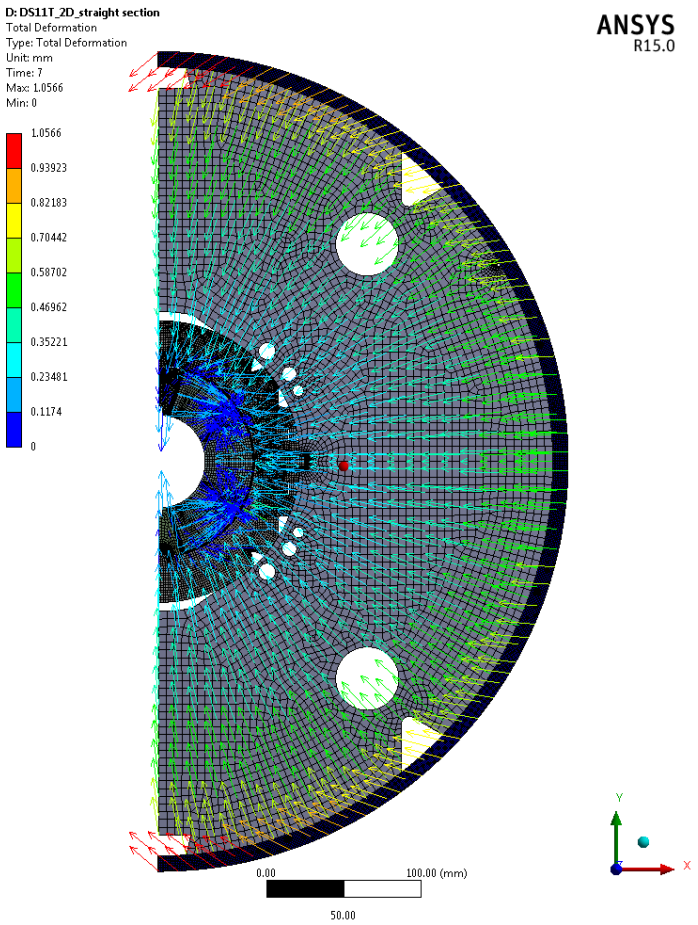


Closing press

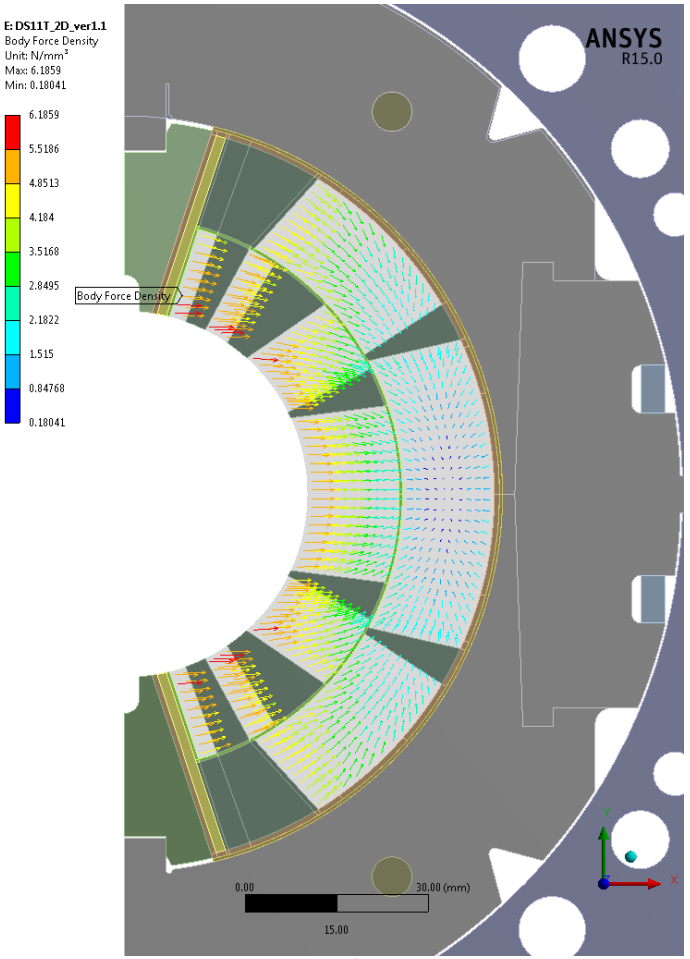


Welding of the shell

ANSYS Setup - cool down_step 7; powering_step 8

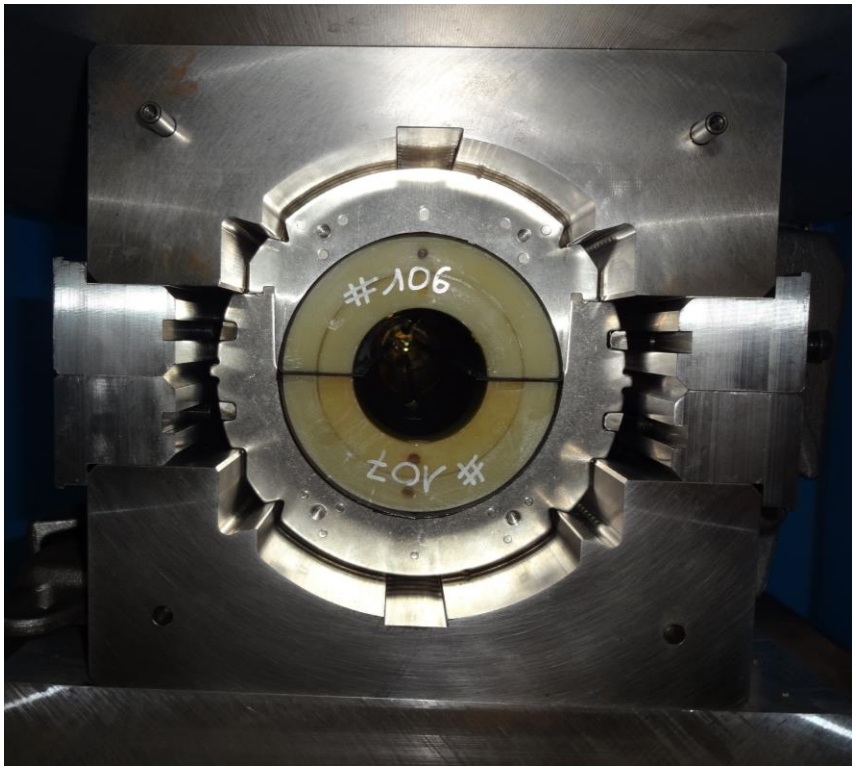


Cool down



powering

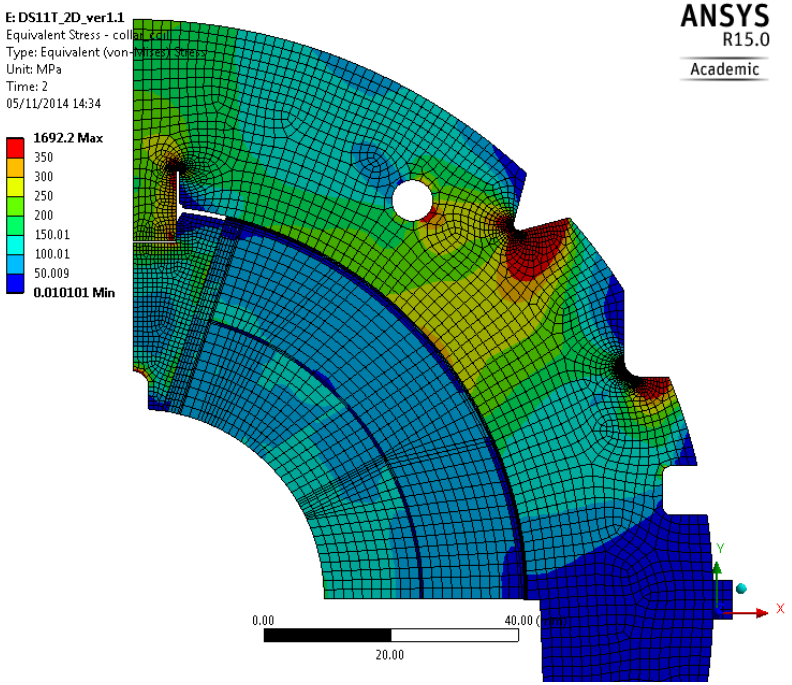
Collaring MBHSP101

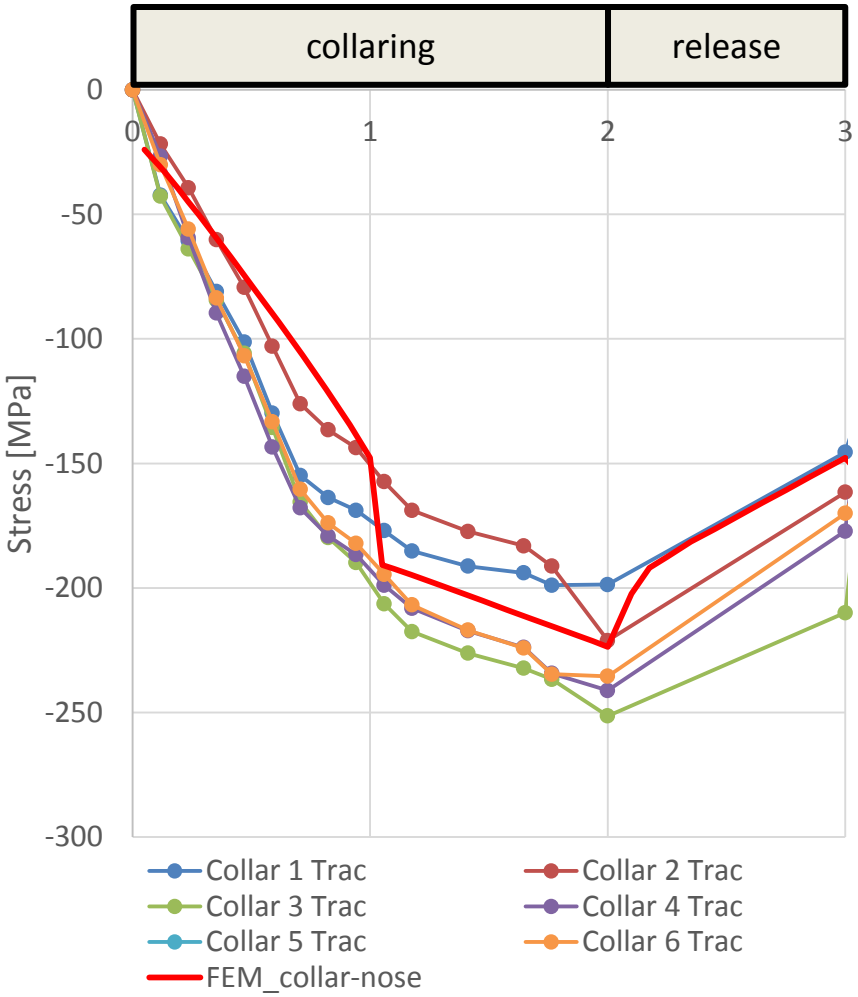


- Principle
  - The mechanical stoppers serve as a spring
  - Stoppers need to be compressed by 0.2mm to insert the keys
    (0.1mm over compression of the assembly)
  - This requires a force of 34MN (measured)

collaring

von mises stress





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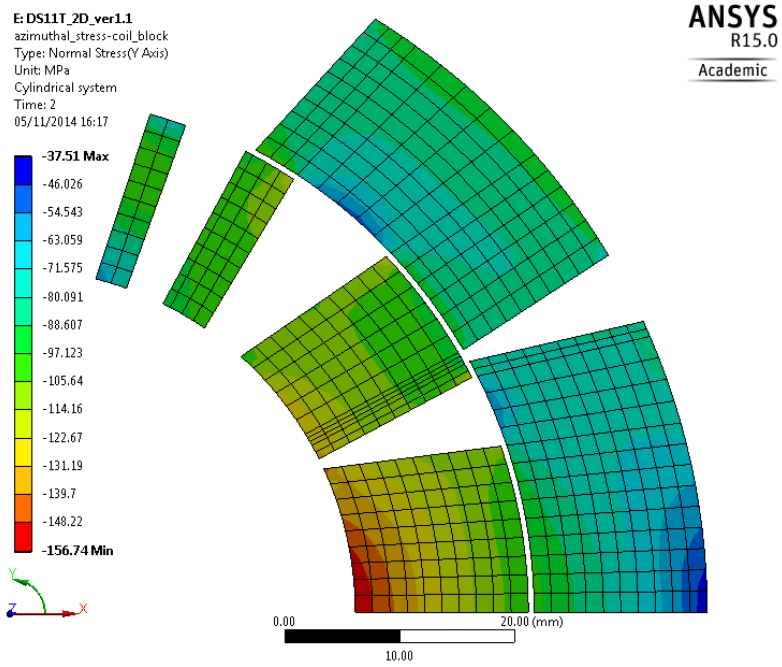
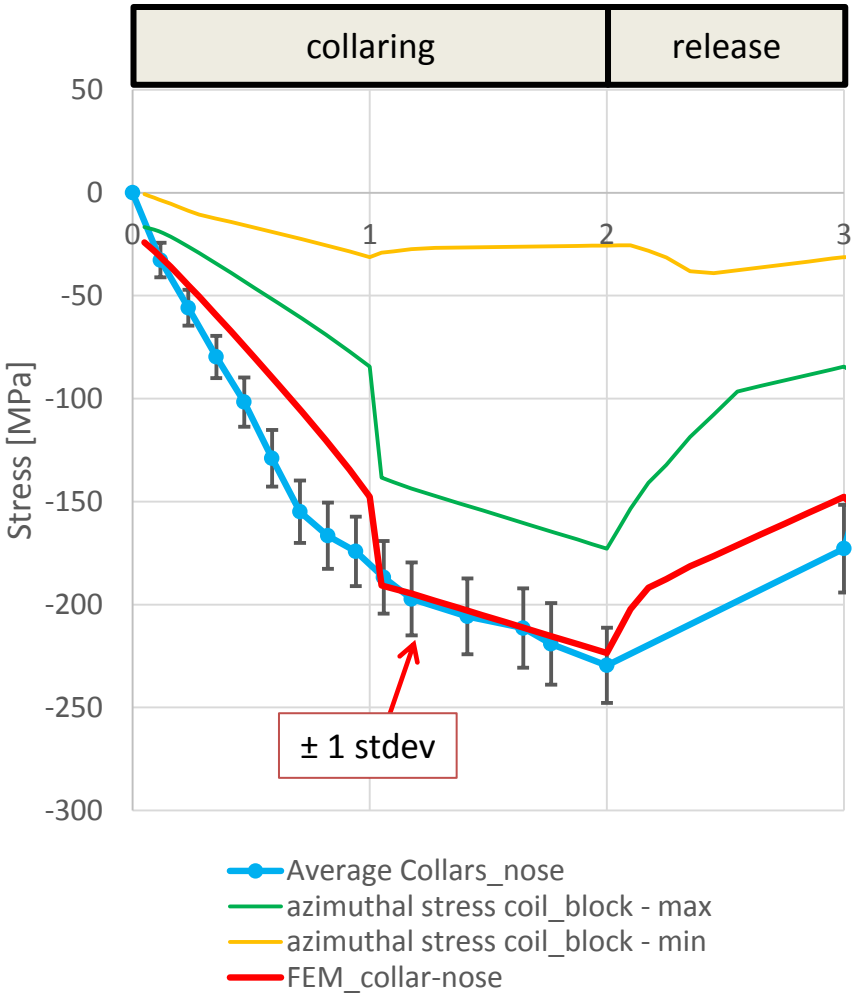
collaring

azimuthal stress





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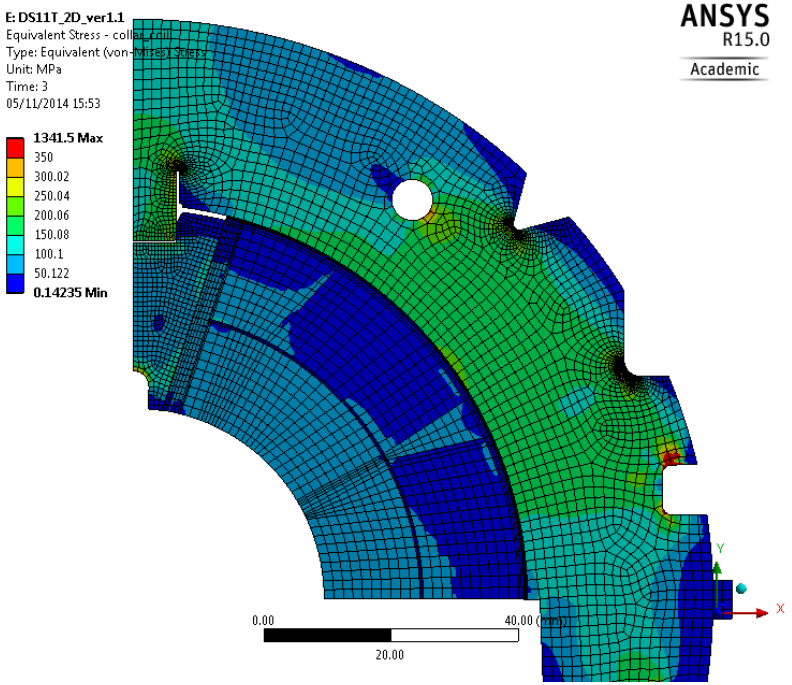
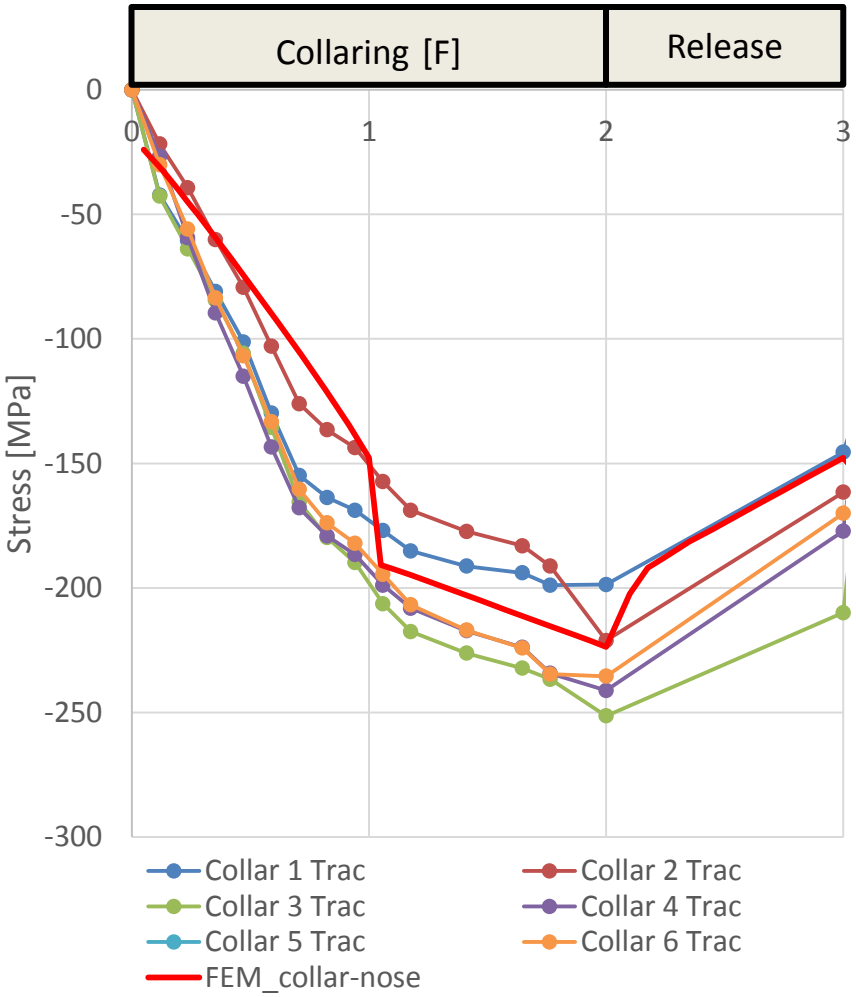
Collared coil – room temperature

von mises stress





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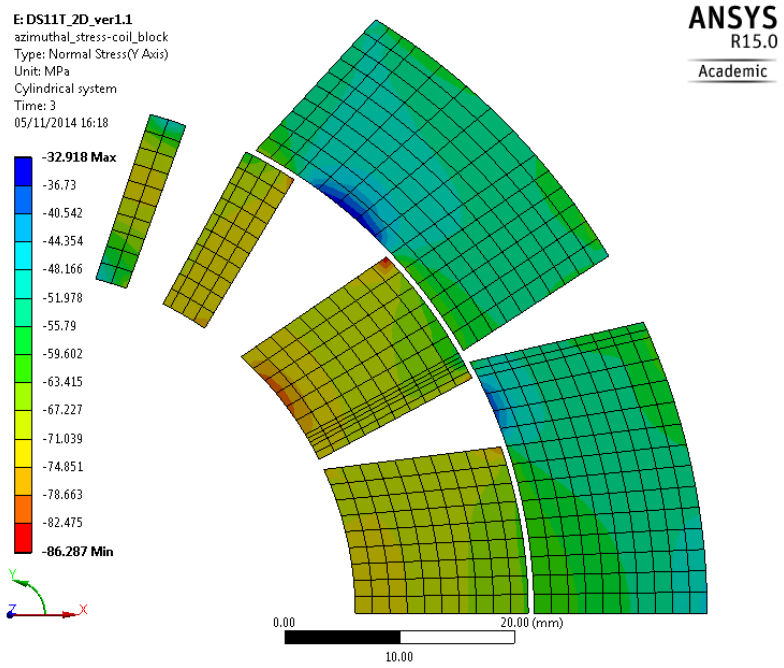
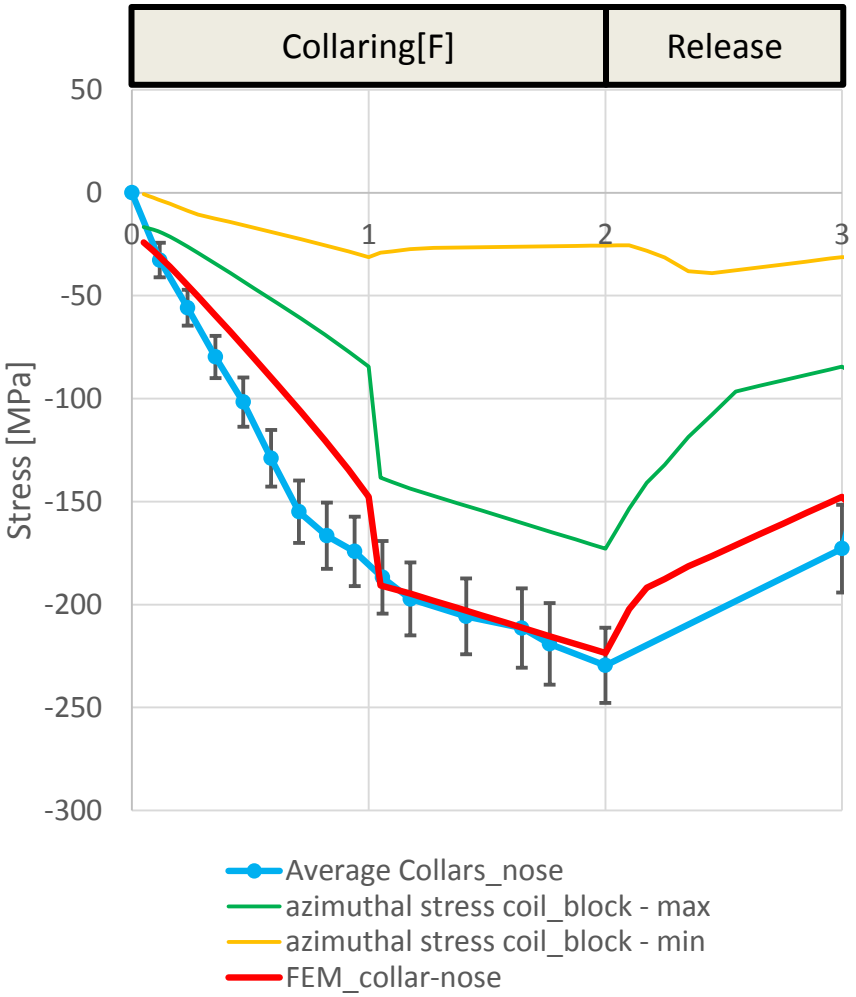
Collared coil – room temperature

azimuthal stress





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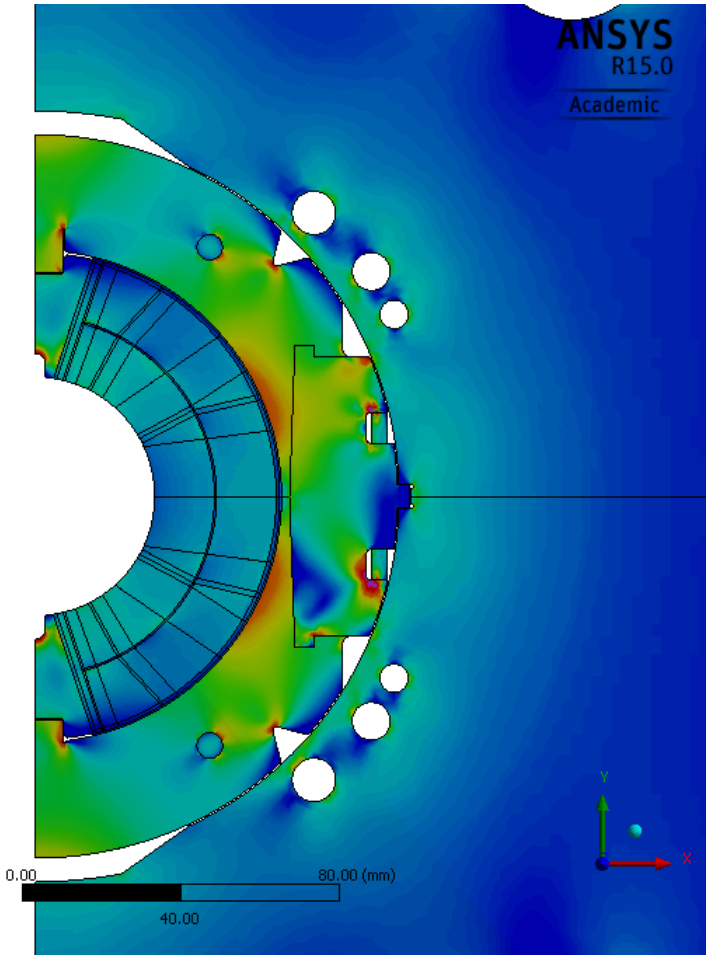
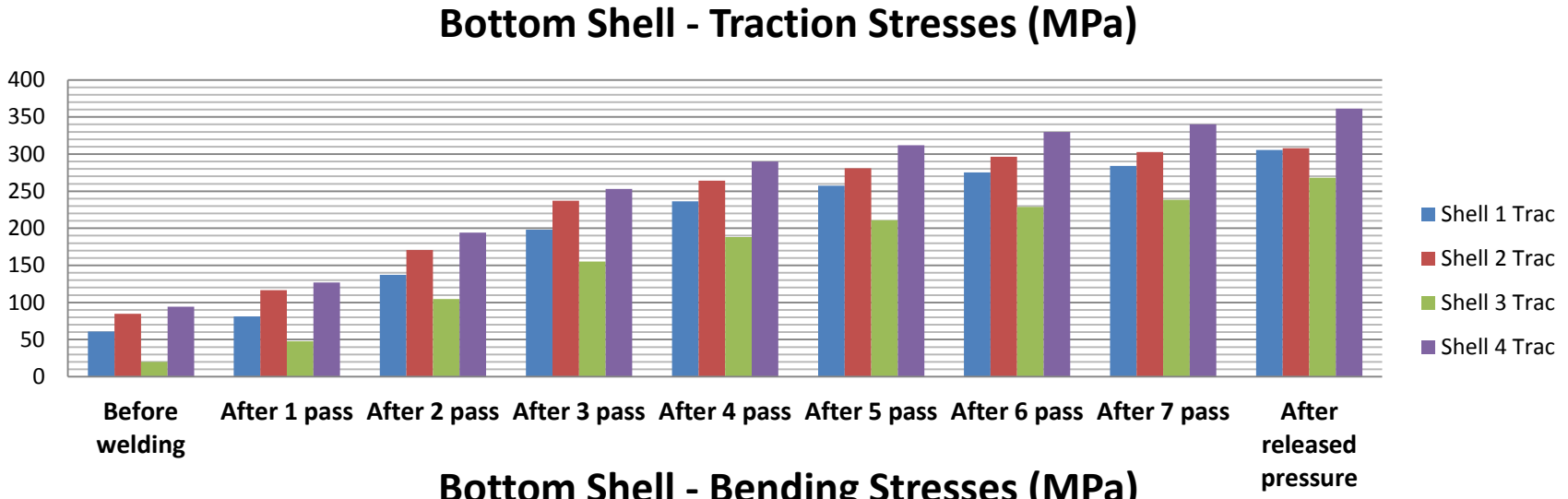
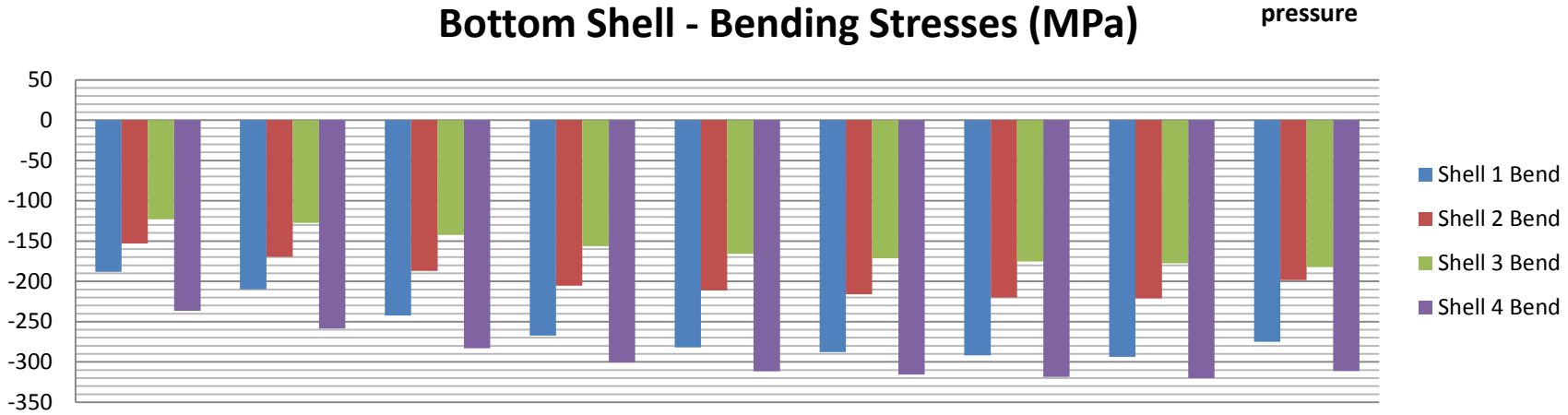
Yoking – Shell welding



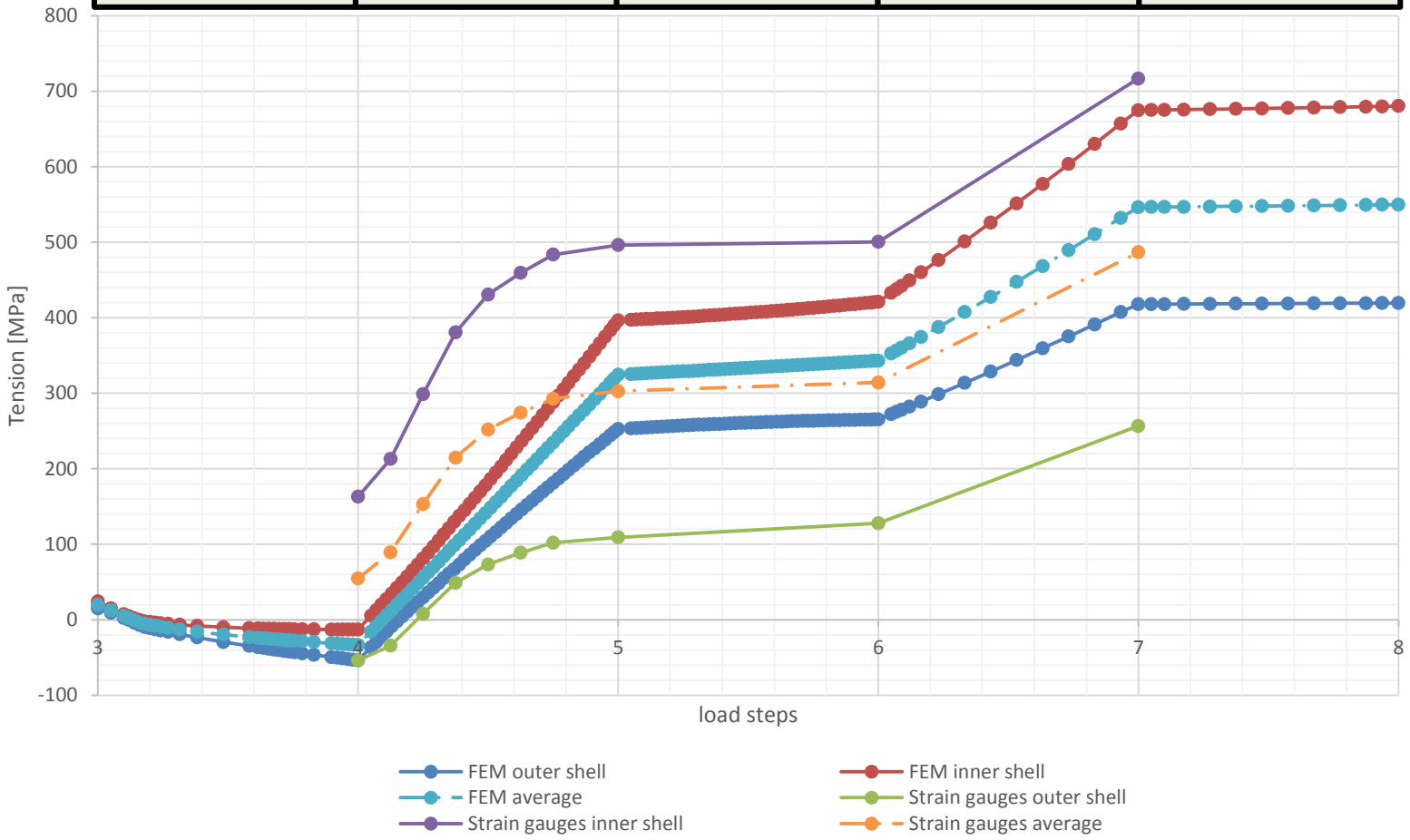
- Steps
  - Closing of the welding press
  - Welding of seven passes
  - Opening of the welding press

Yoking – Shell welding



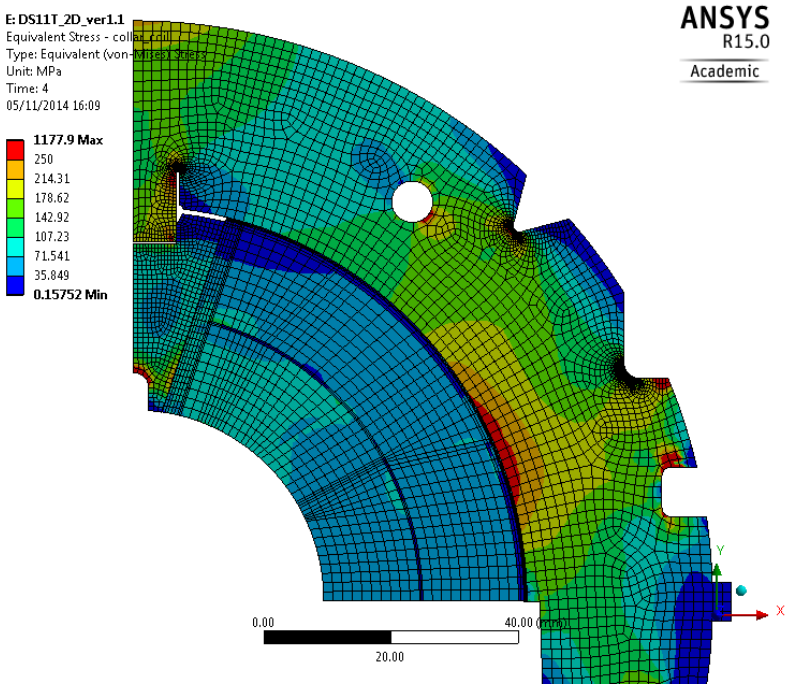


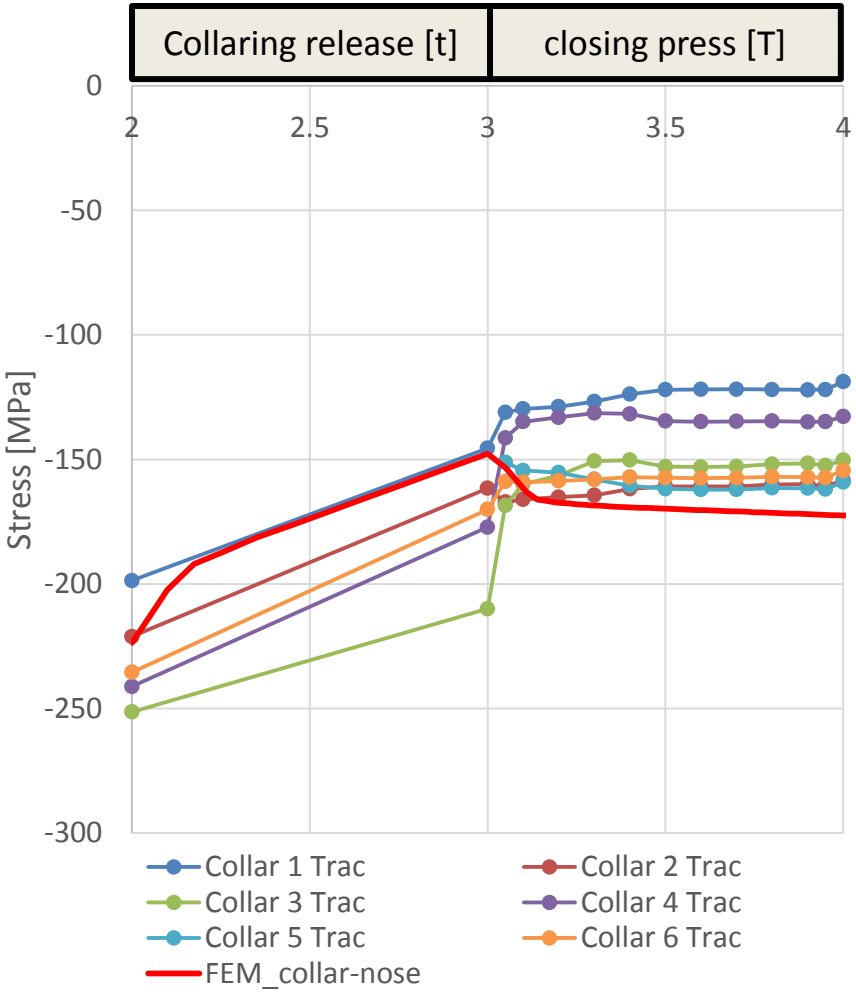
closing press [F]	Welding [passes]	opening press [t]	cool down [T]	11.85kA [A]



Yoking – press closed

von mises stress





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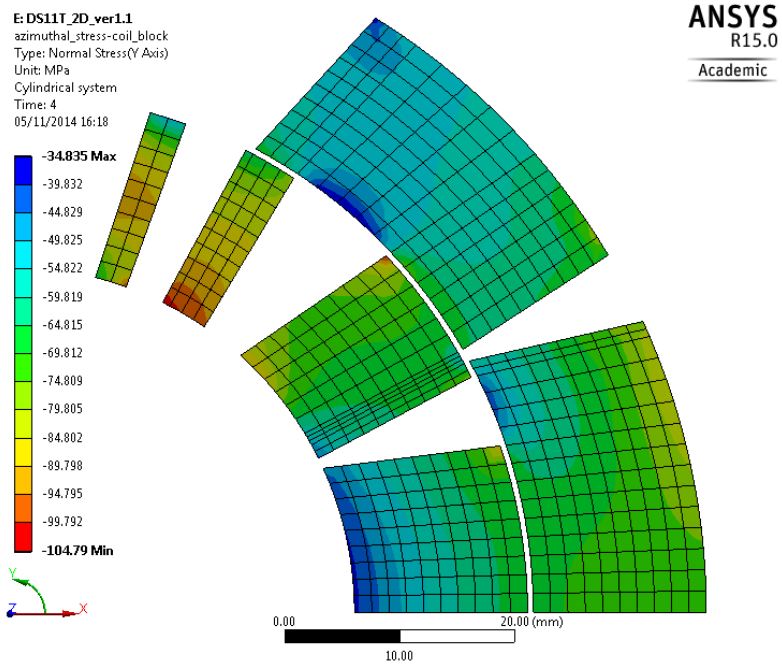
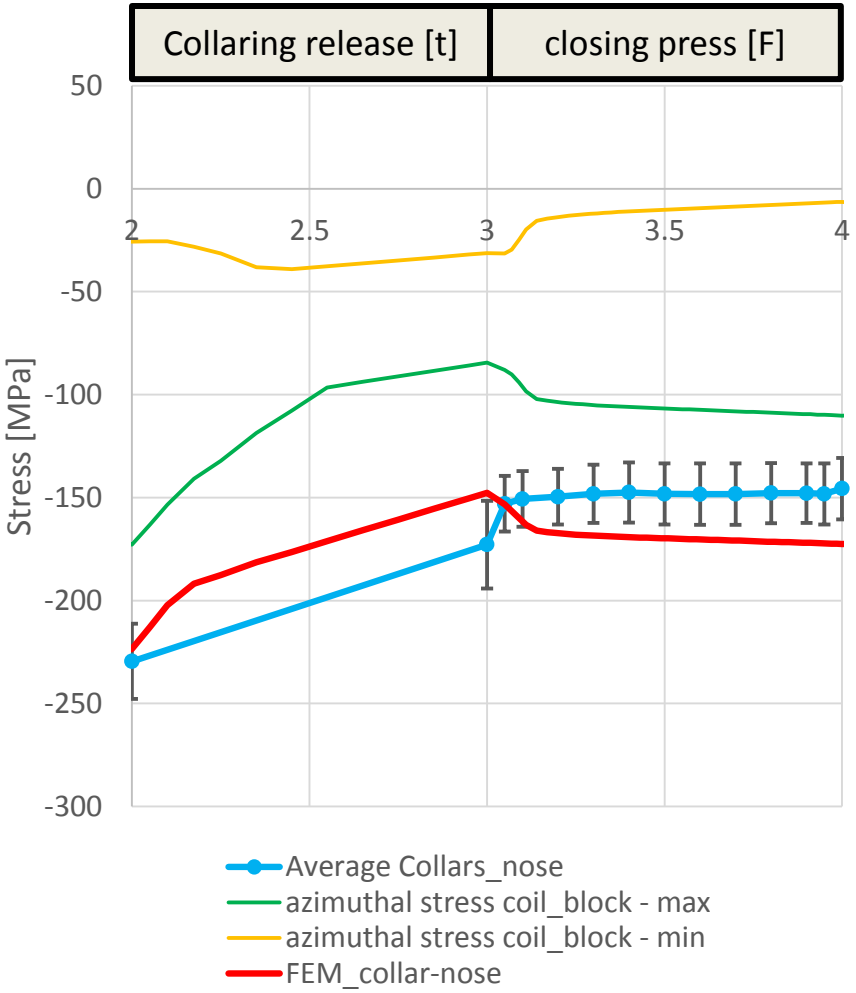
Yoking – press closed

azimuthal stress





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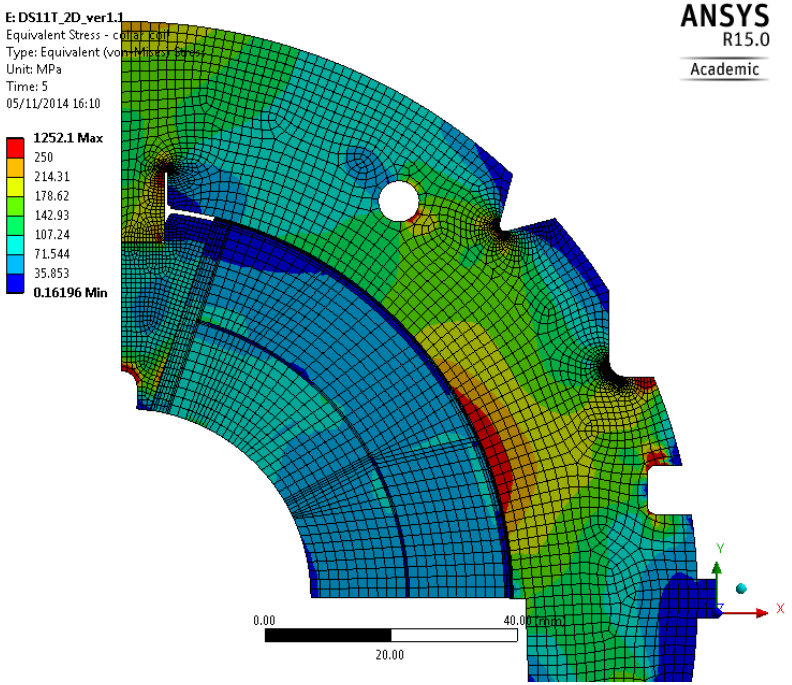
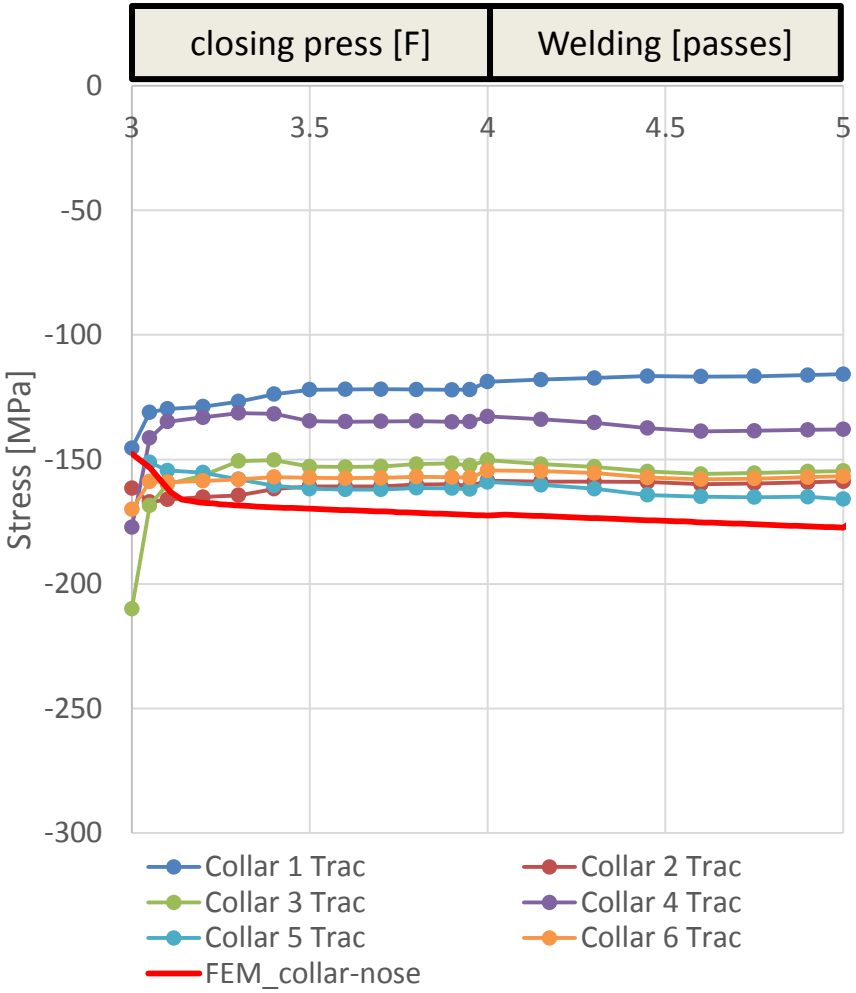
Yoking – welding

von mises stress





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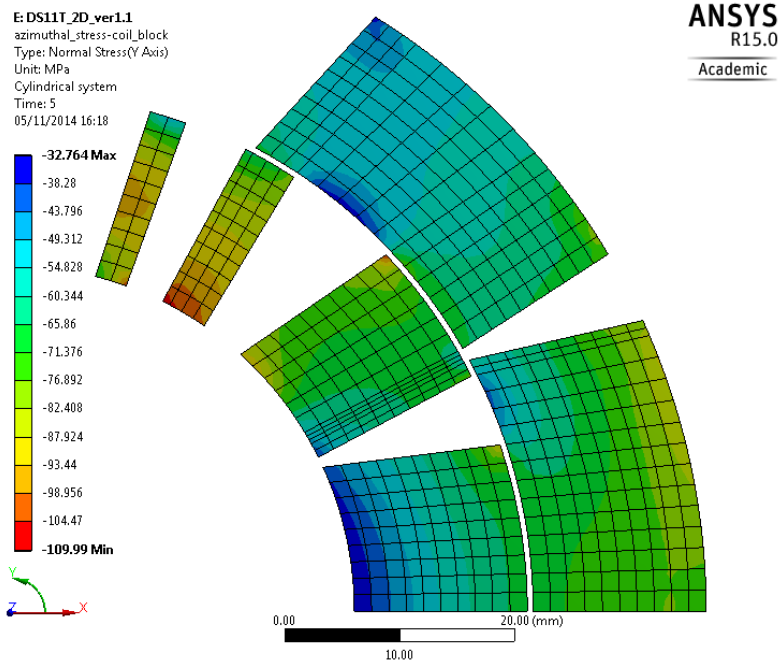
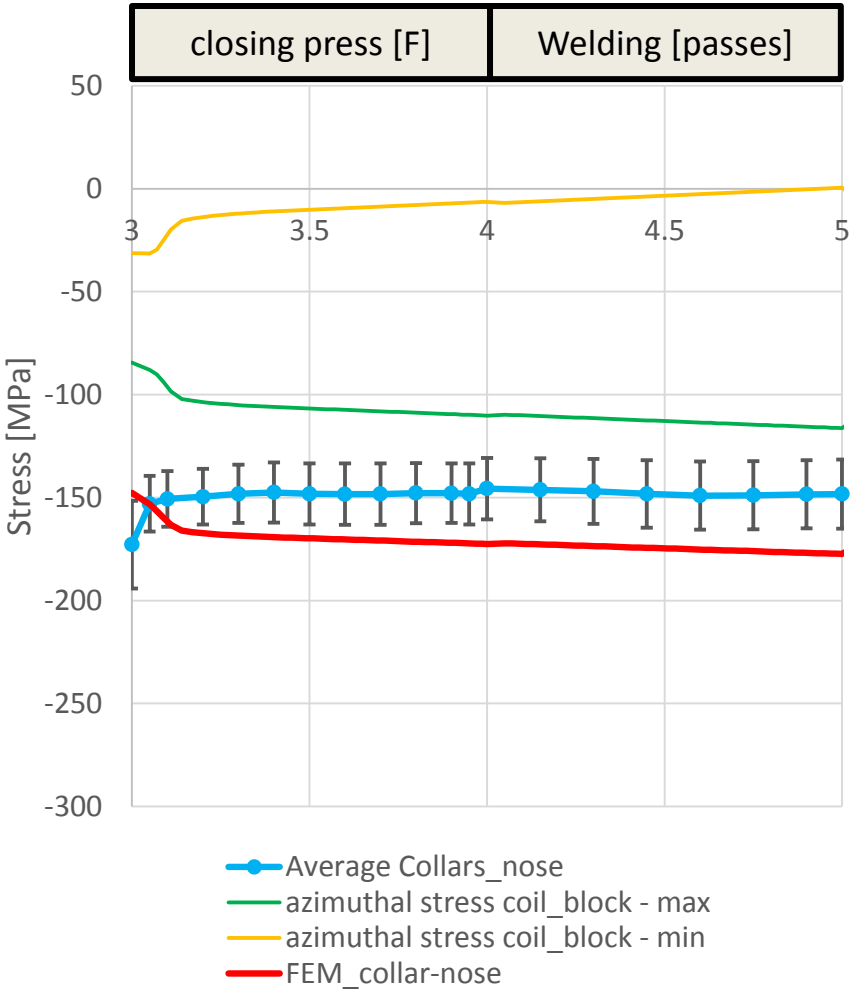
Yoking – welding

azimuthal stress





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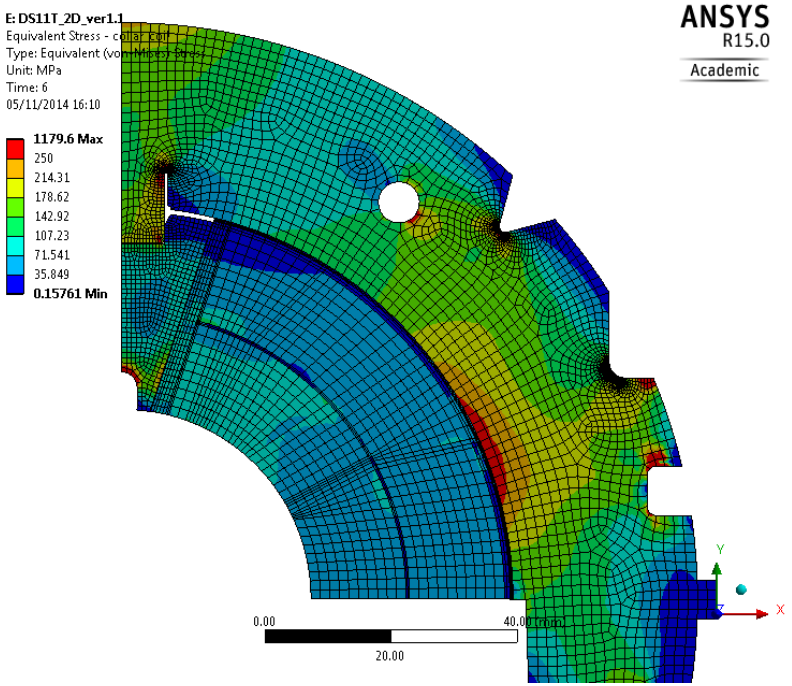
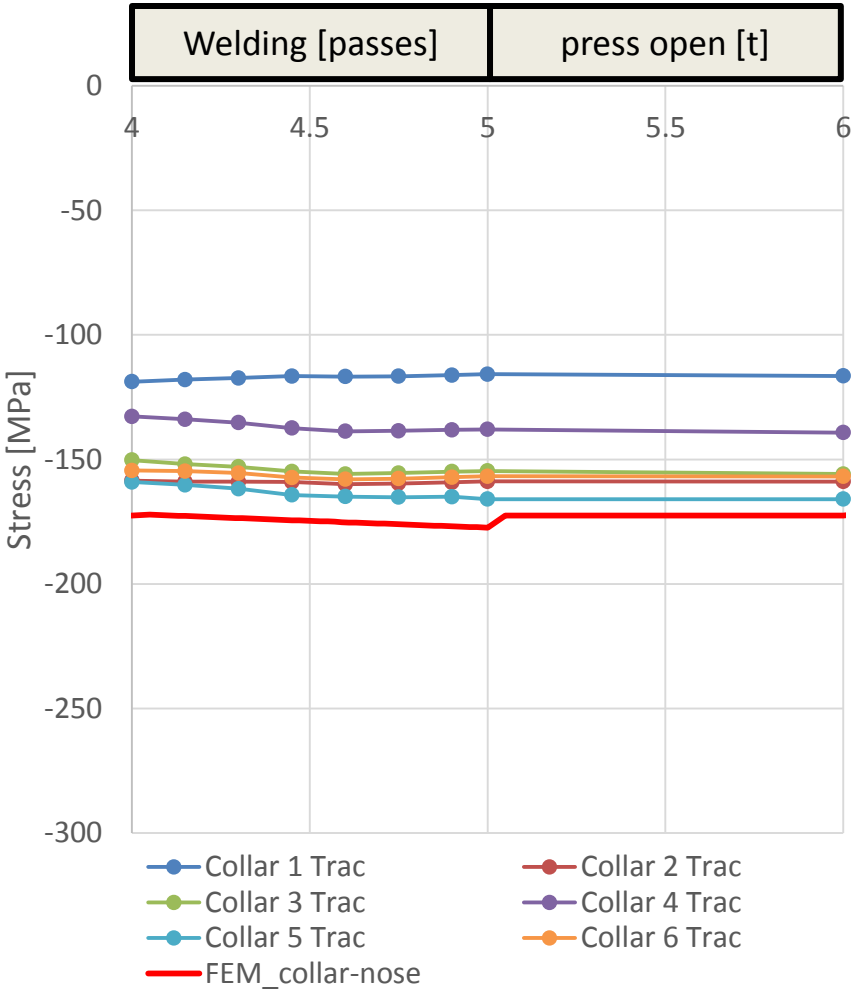
Yoking – press open

von mises stress





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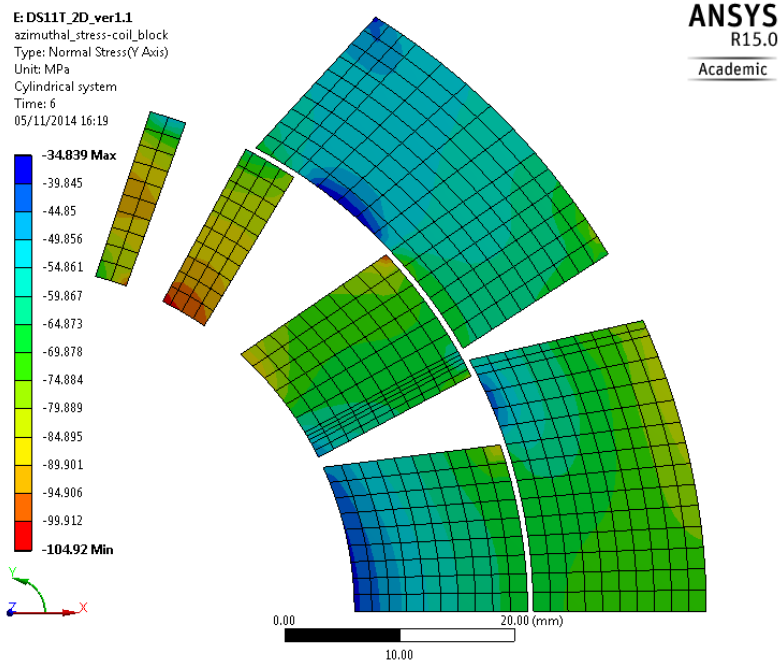
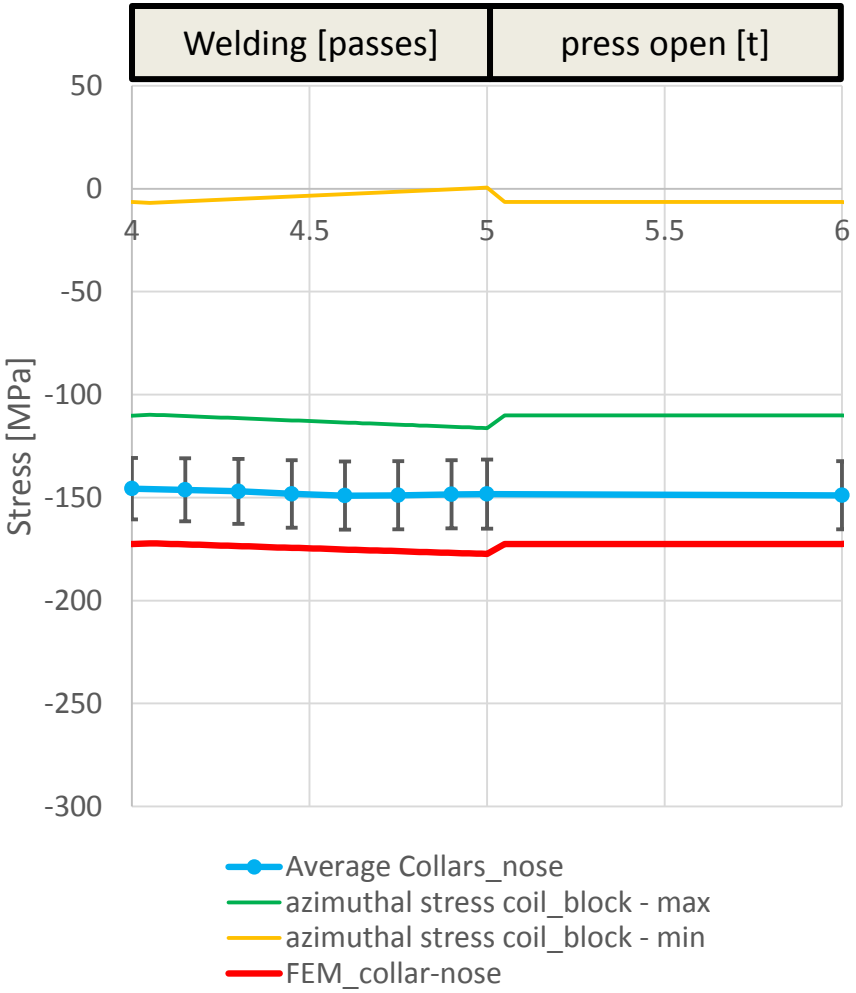
Yoking – press open

azimuthal stress





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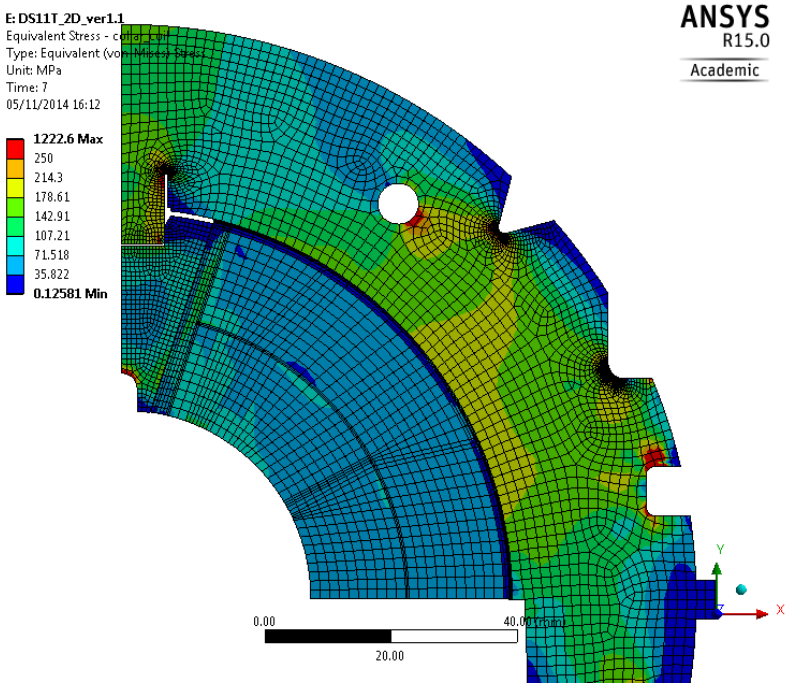
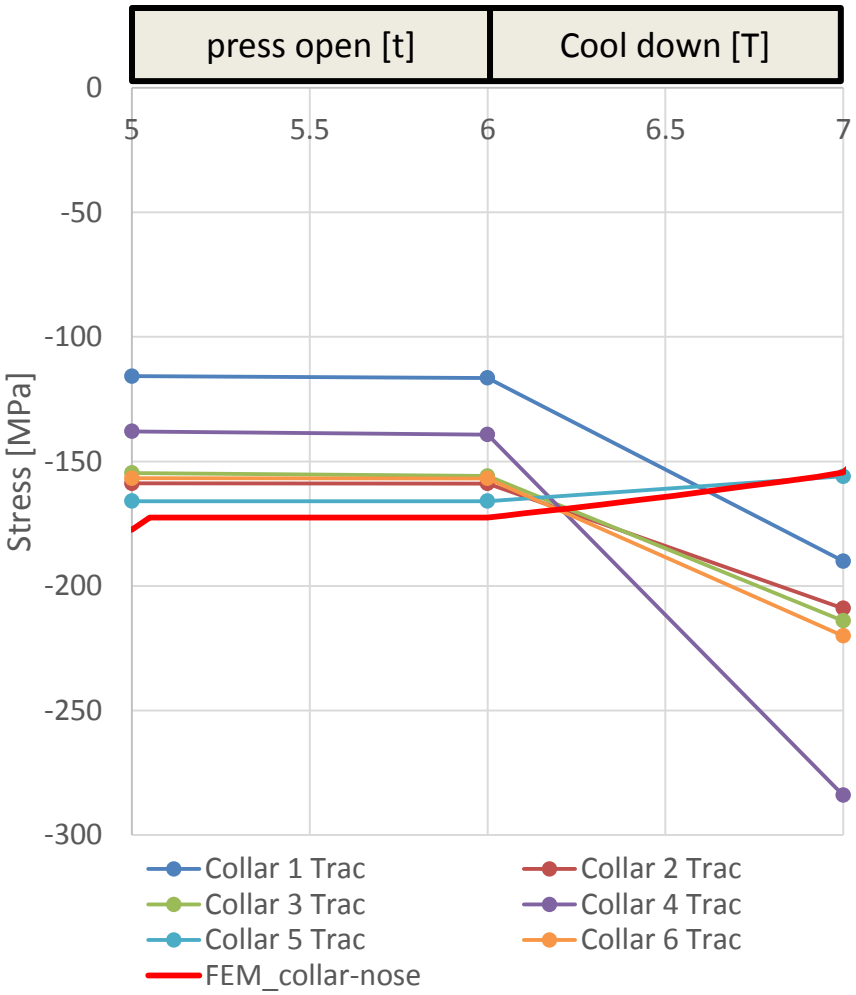
Cool down

von mises stress





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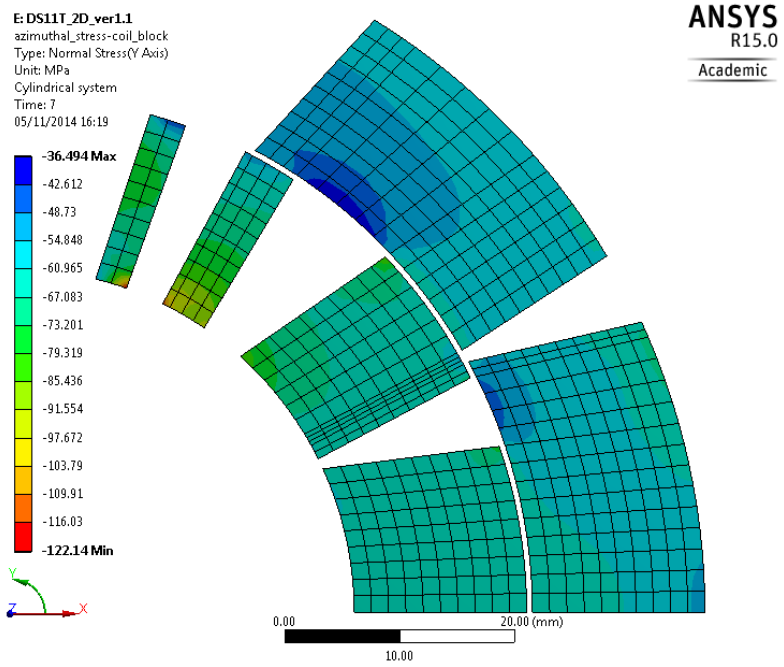
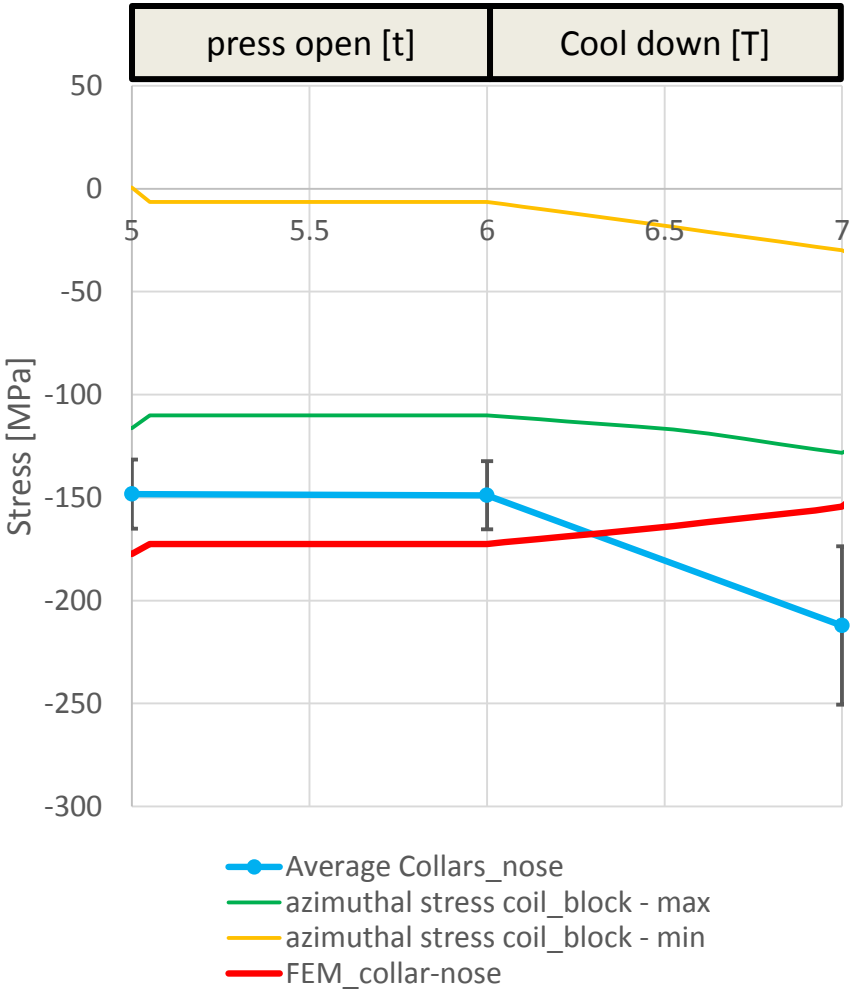
Cool down

azimuthal stress





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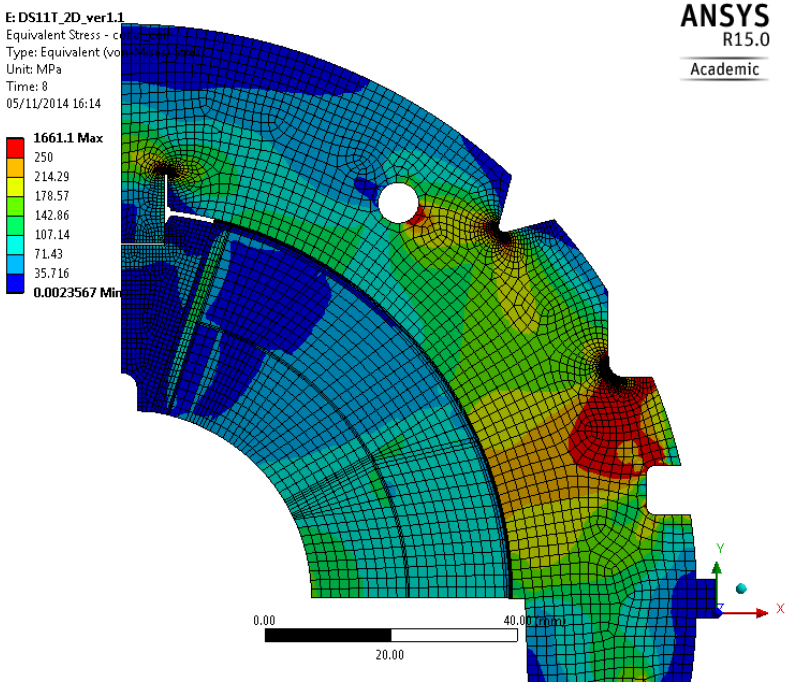
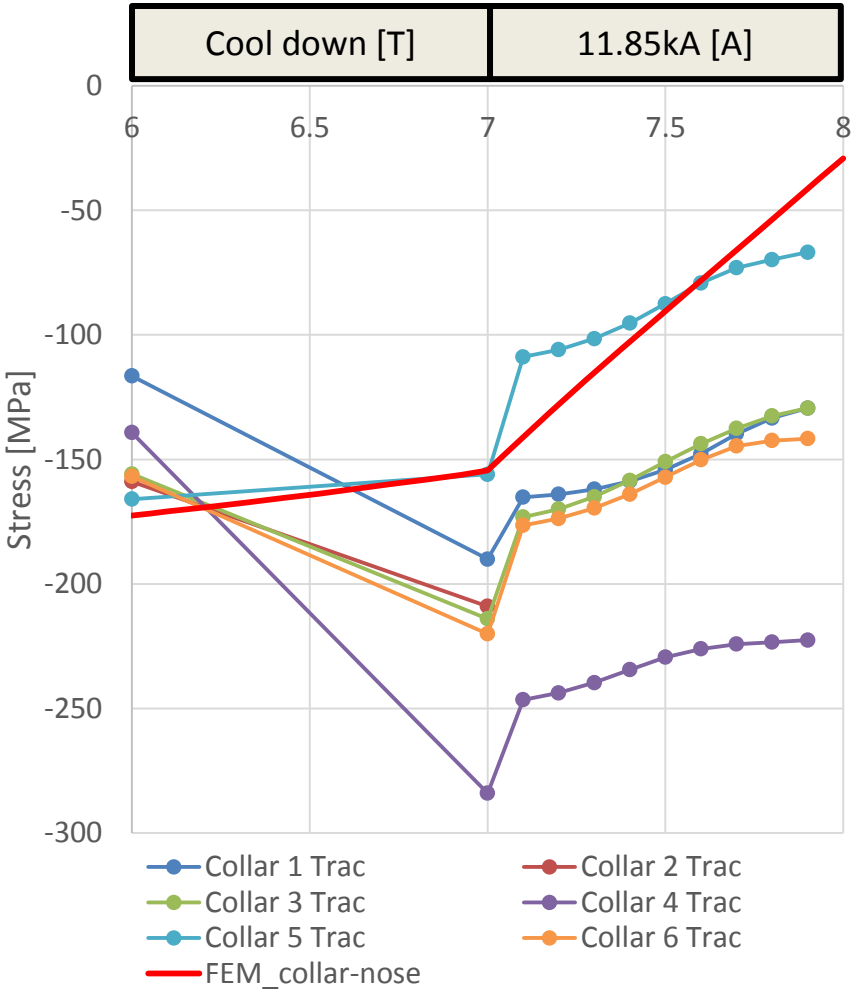
Powering 11.85kA

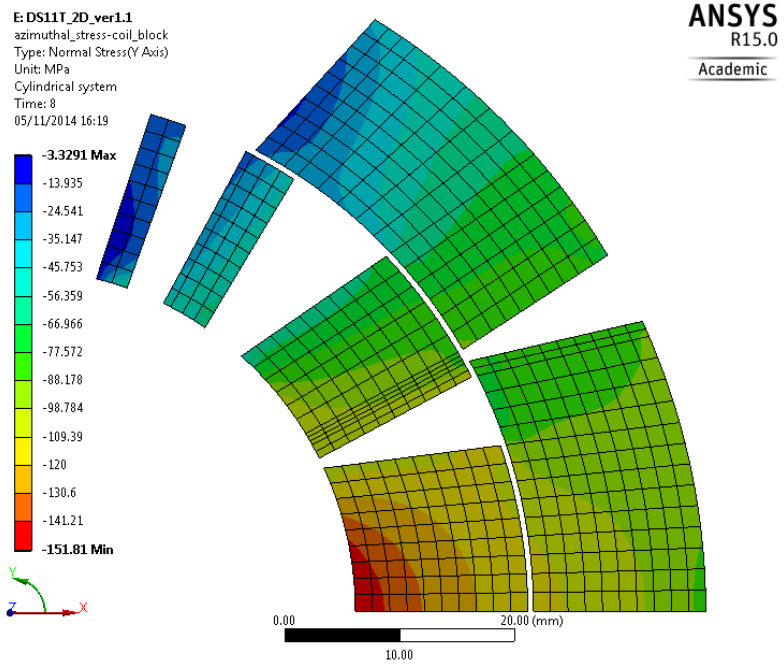
von mises stress

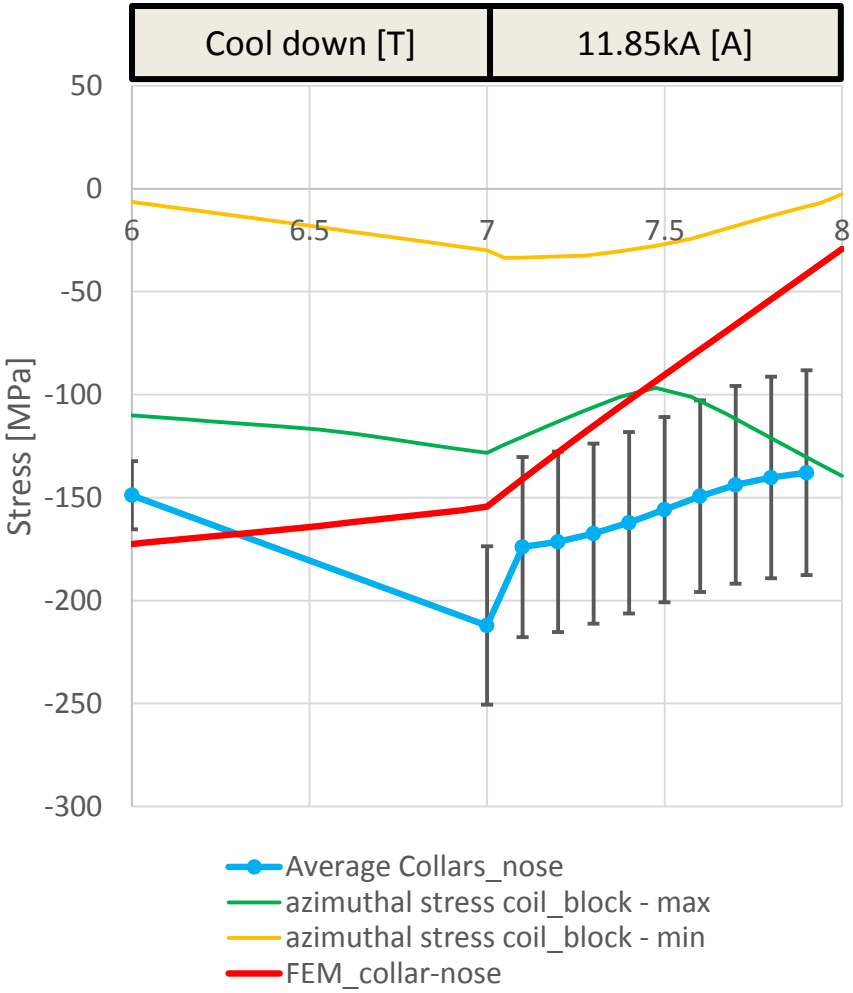




Powering 11.85kA

azimuthal stress





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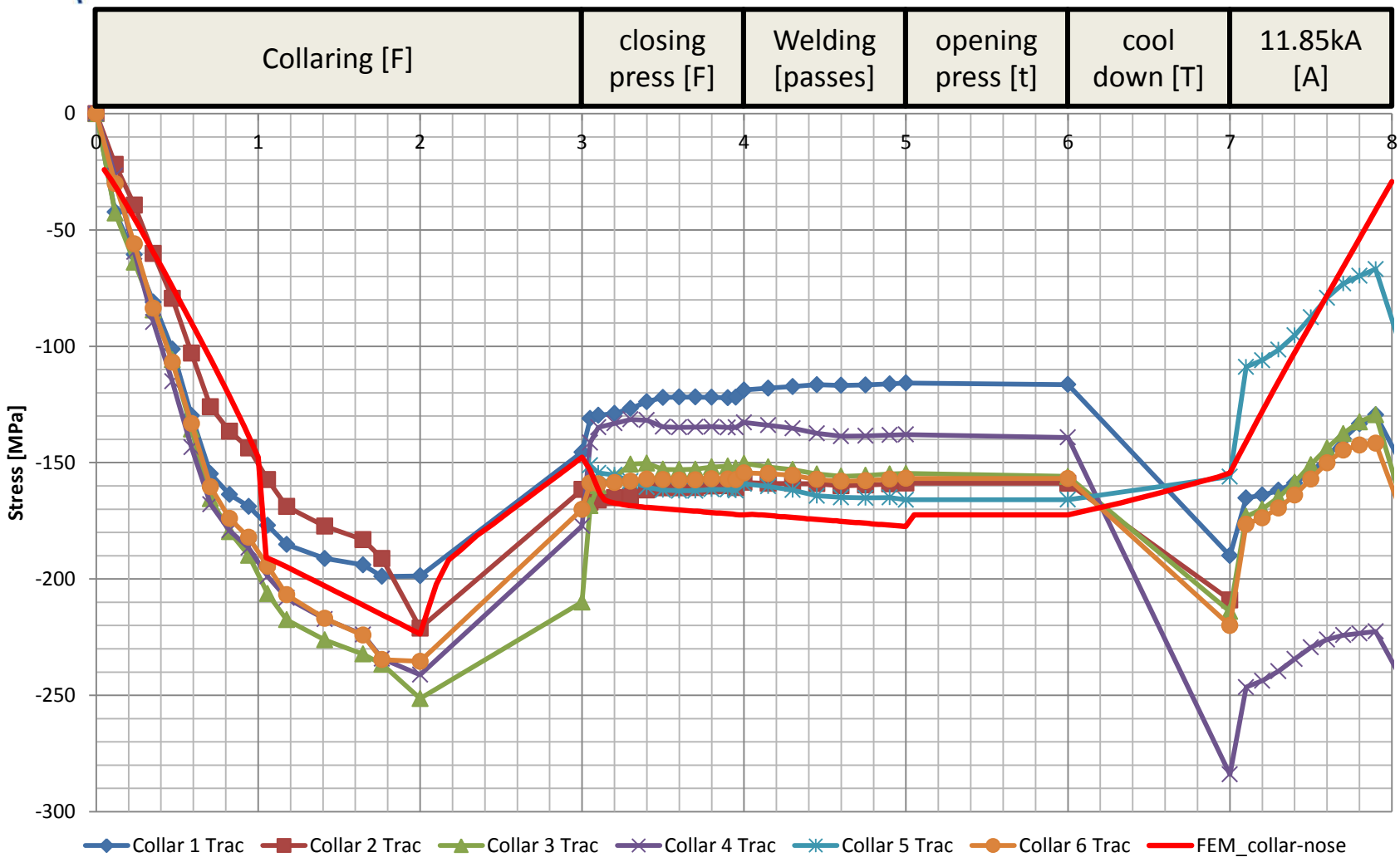
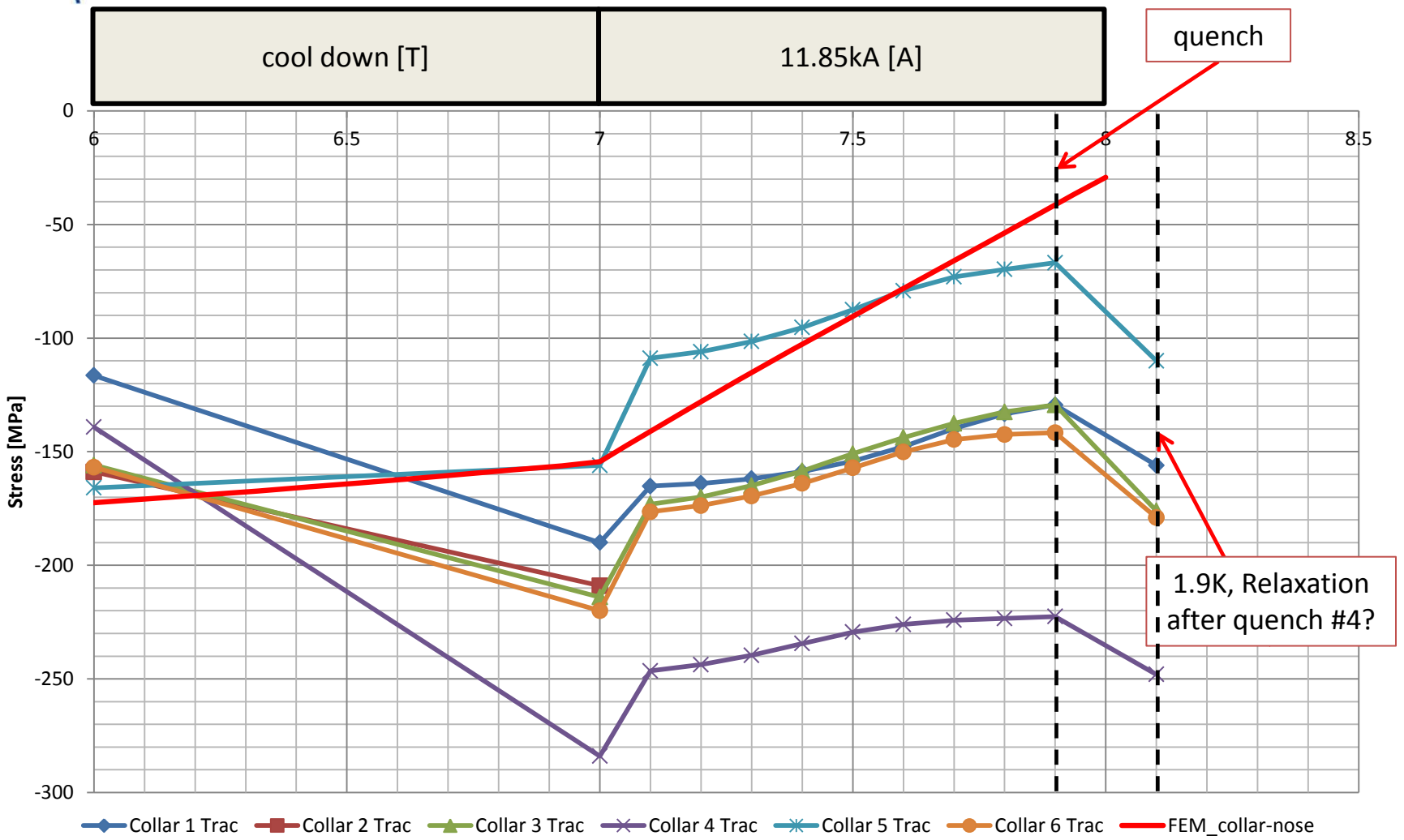
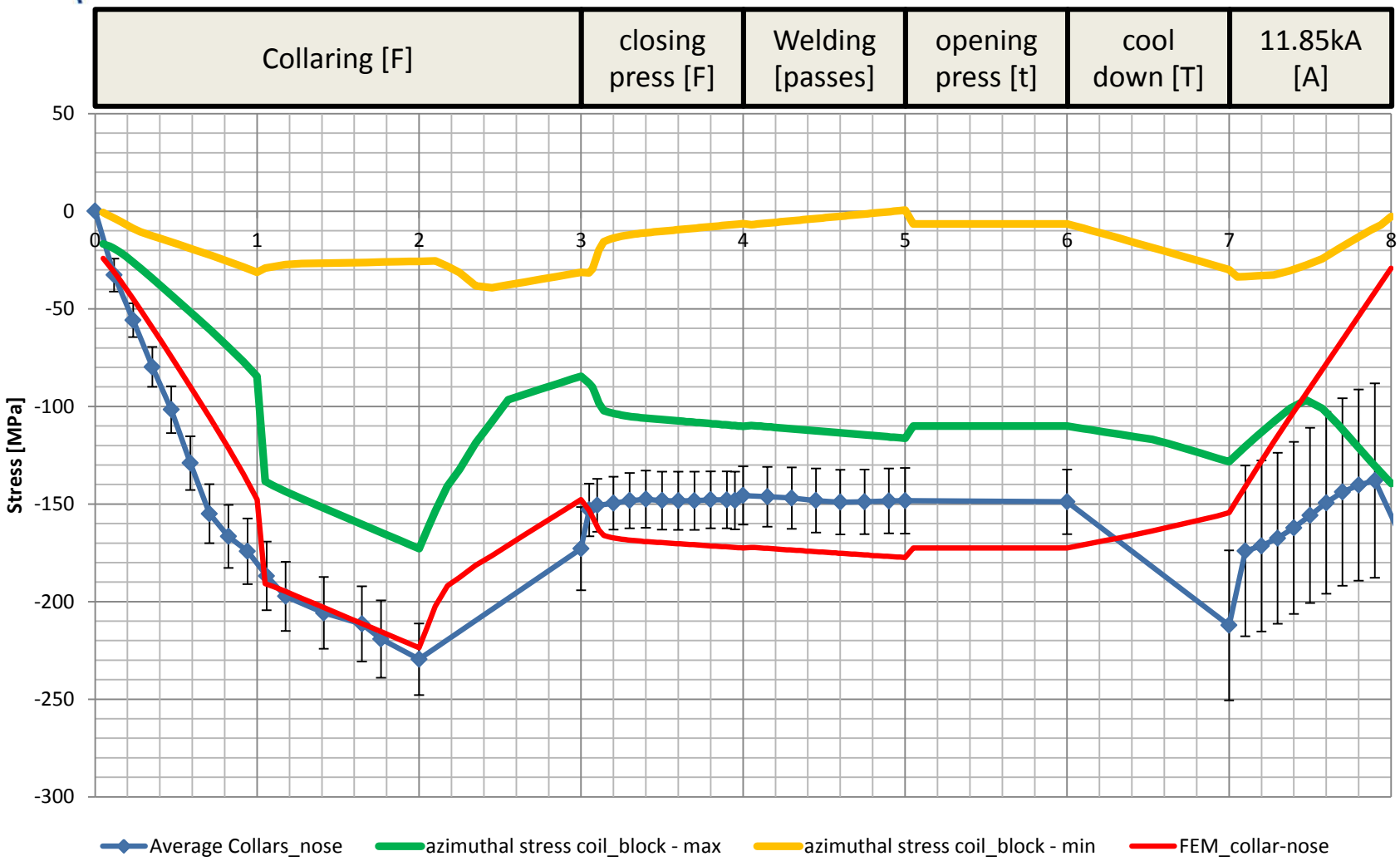
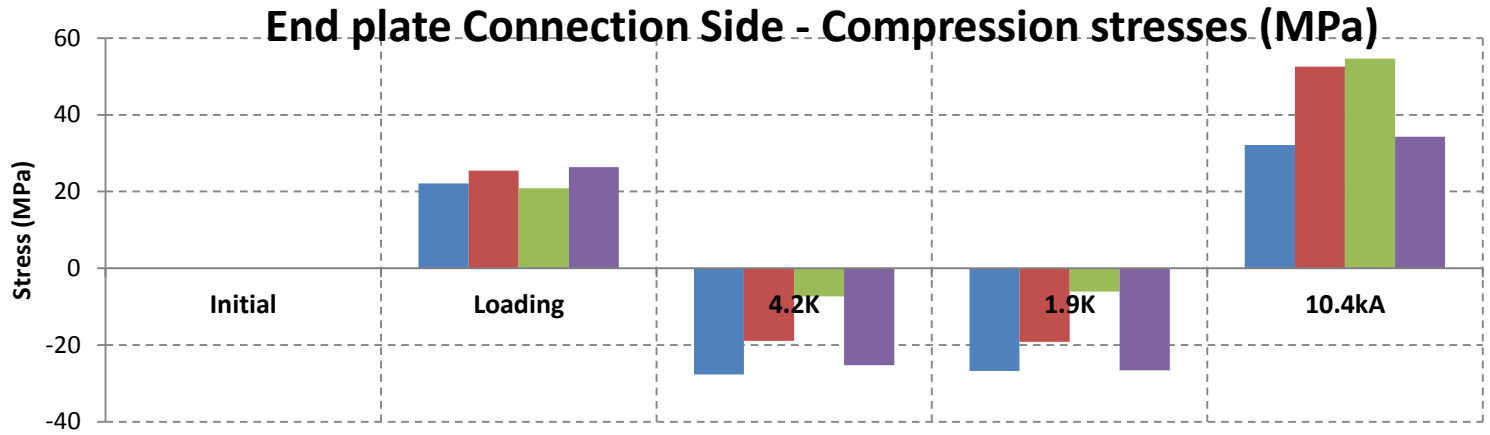
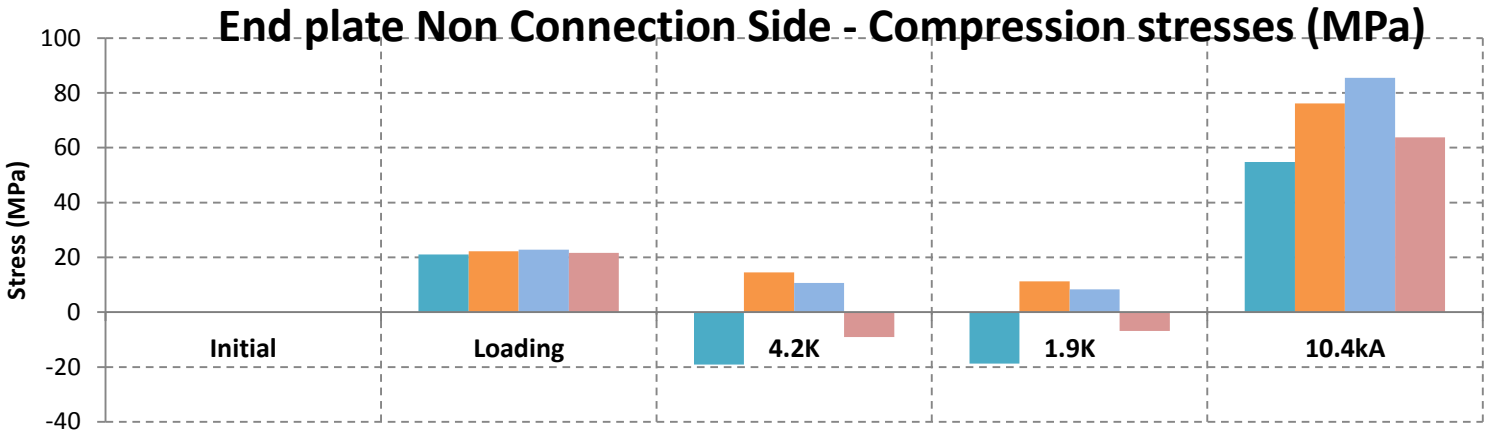






Loading bullet gauges





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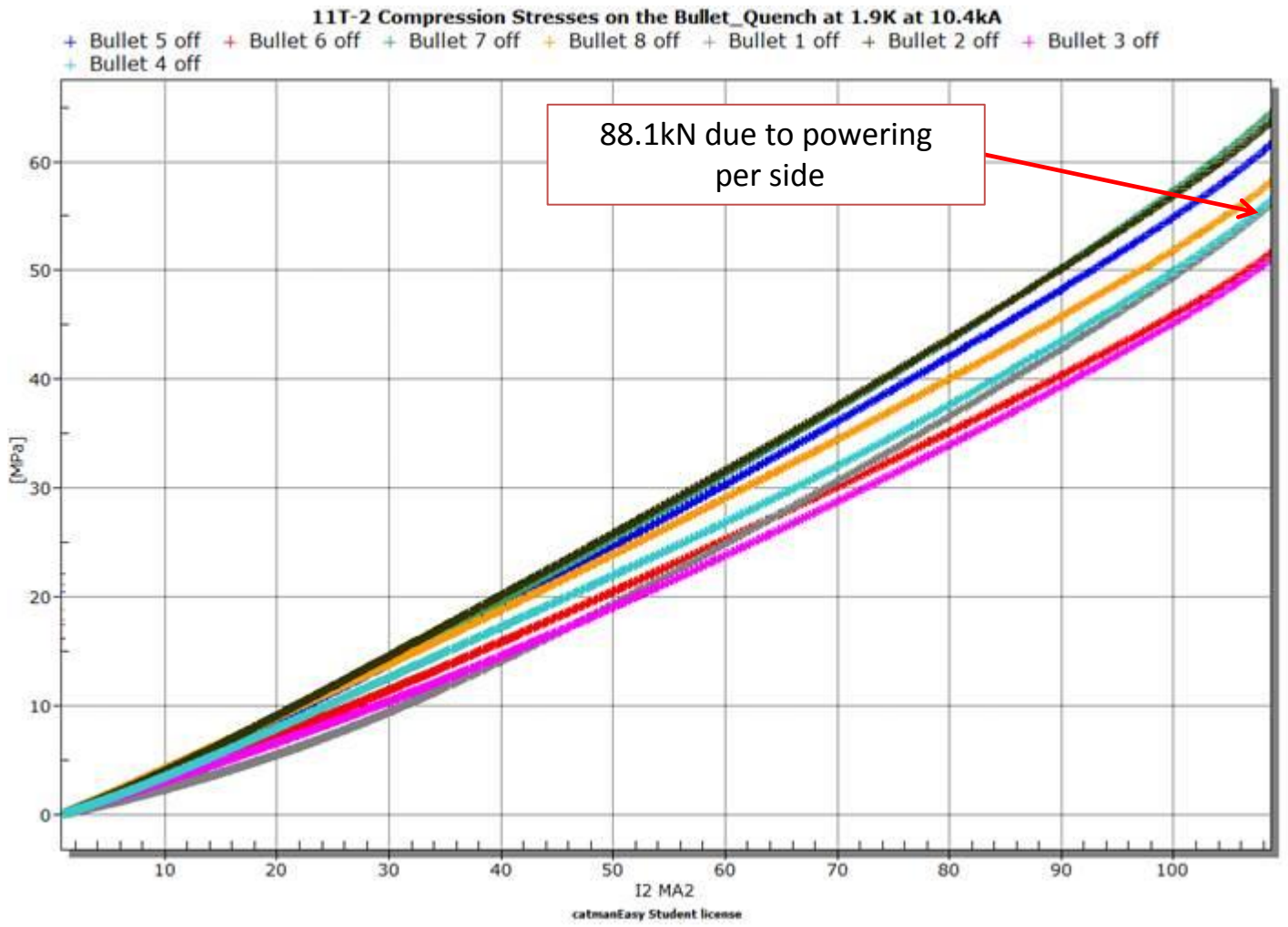
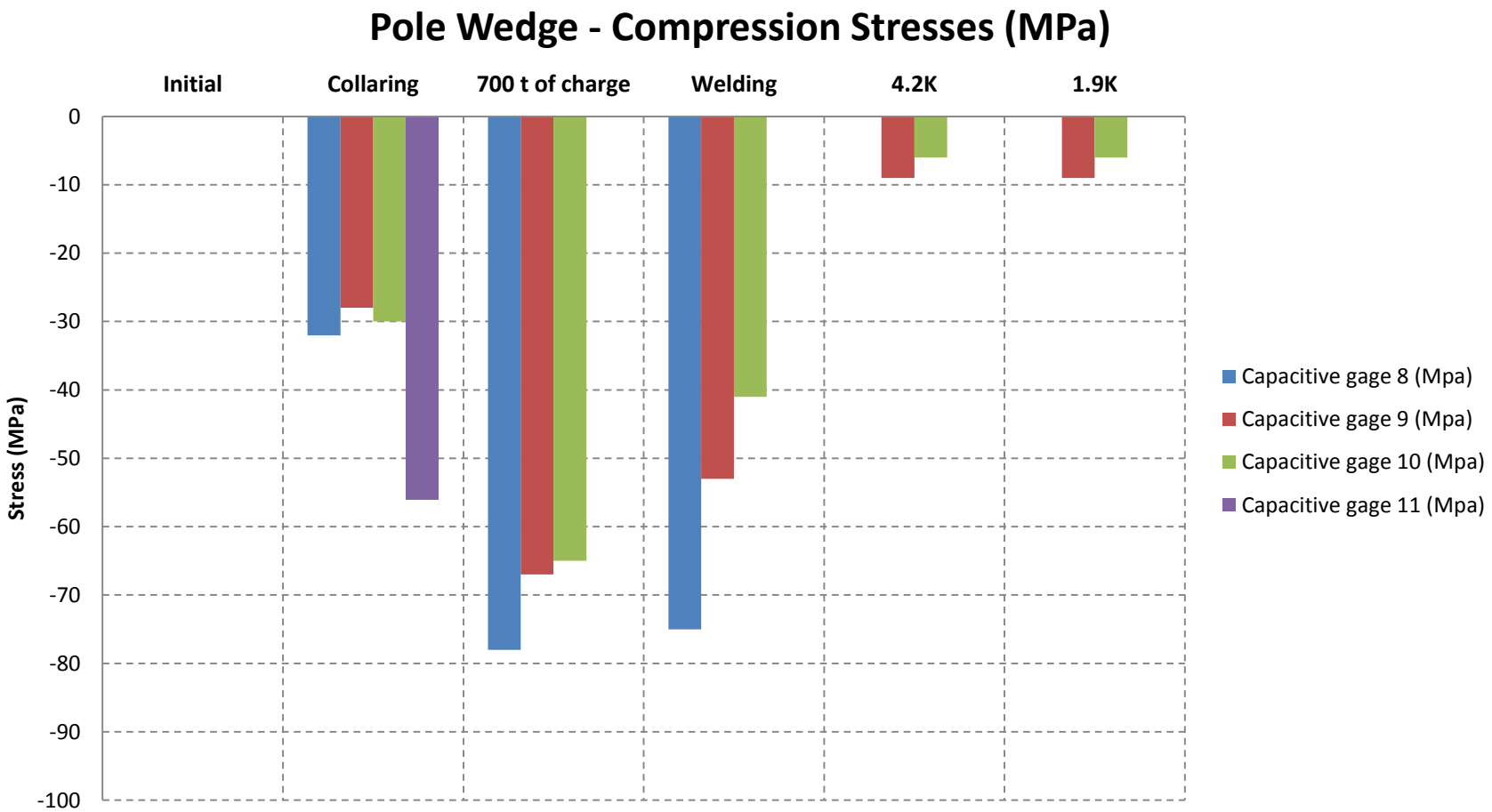
EN/MME Philippe Grosclaude
<philippe.grosclaude@cern.ch>

Loading bullet gauges – delta during powering



EN/MME Philippe Grosclaude
<philippe.grosclaude@cern.ch>

Cap. Gauge – loading pole



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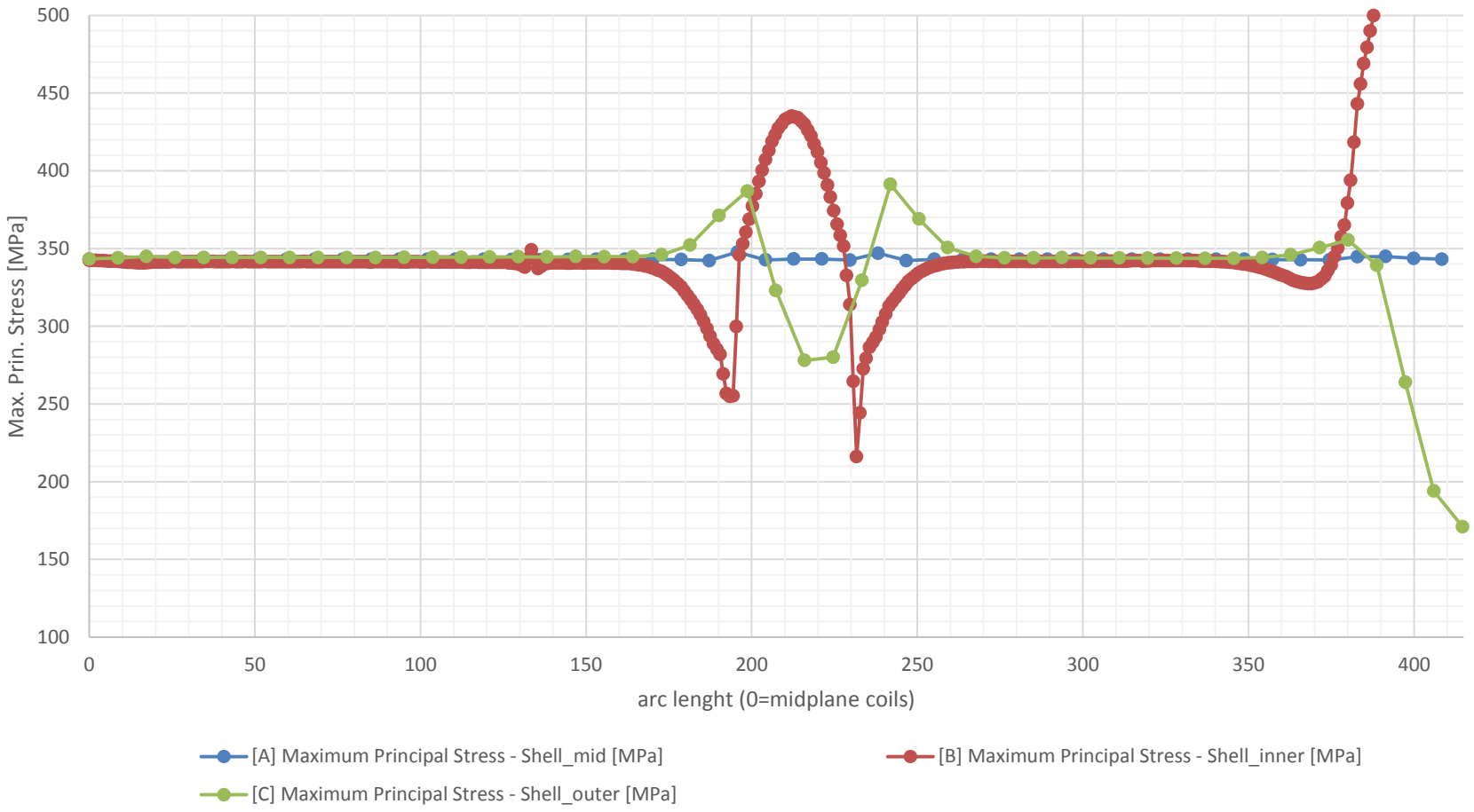
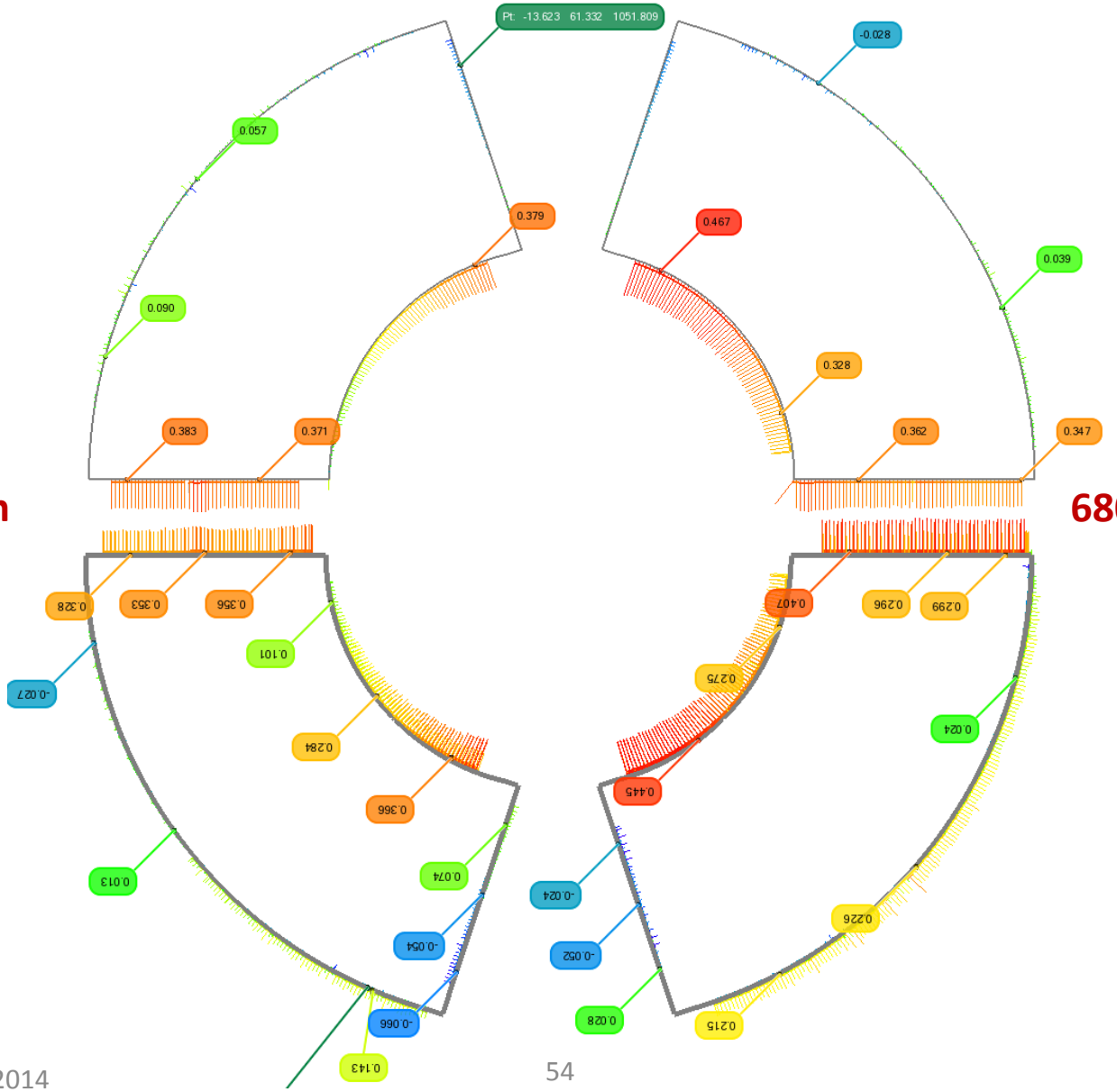
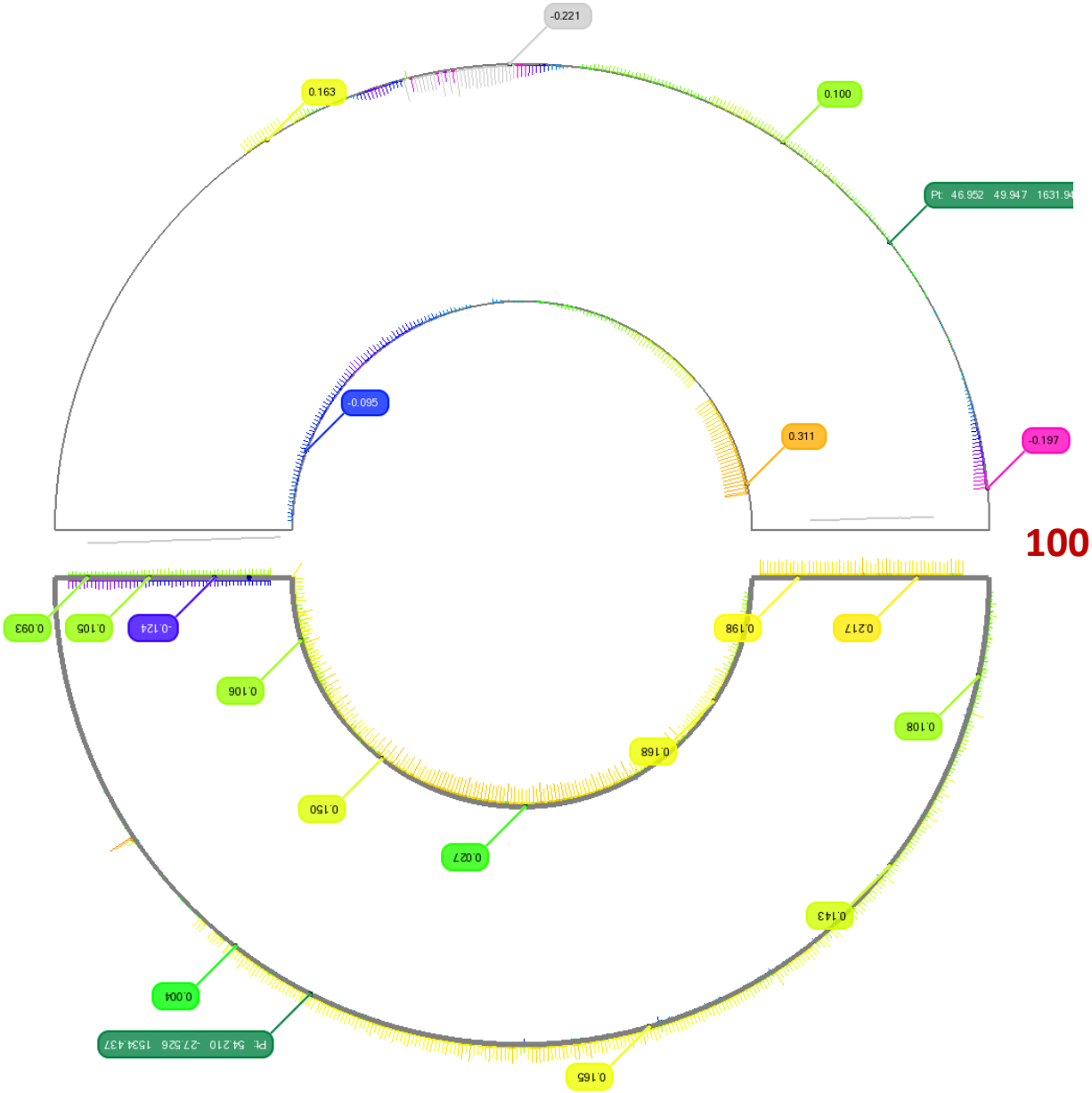
Stress after welding, Shell






-0.221
0.163
0.100
Pt: 46.952 49.947 1631.94
-0.095
0.311
-0.197
50µm
100 µm
0.093
0.105
-0.124
0.106
0.198
0.217
0.108
0.168
0.150
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0.143
0.004
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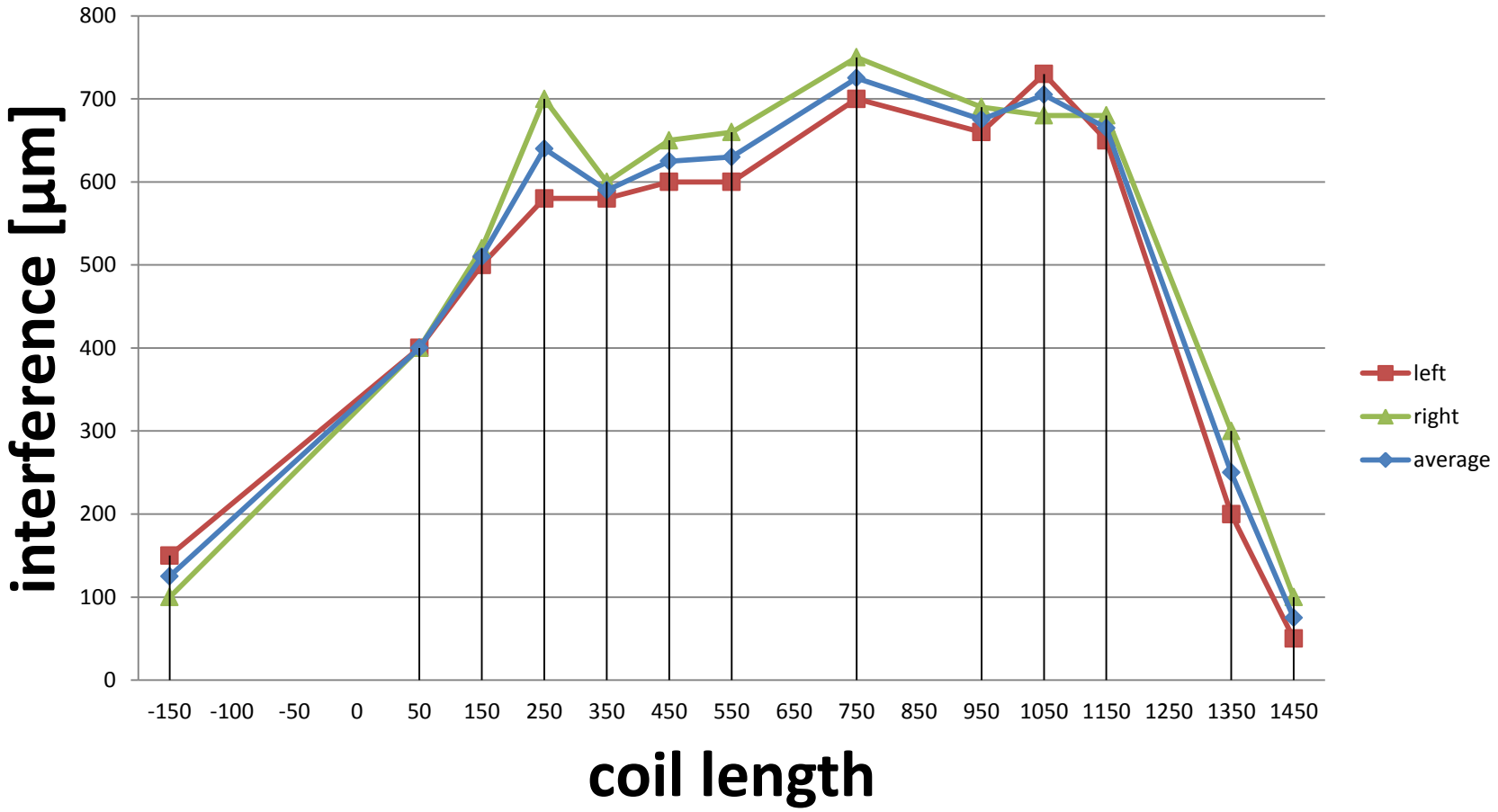
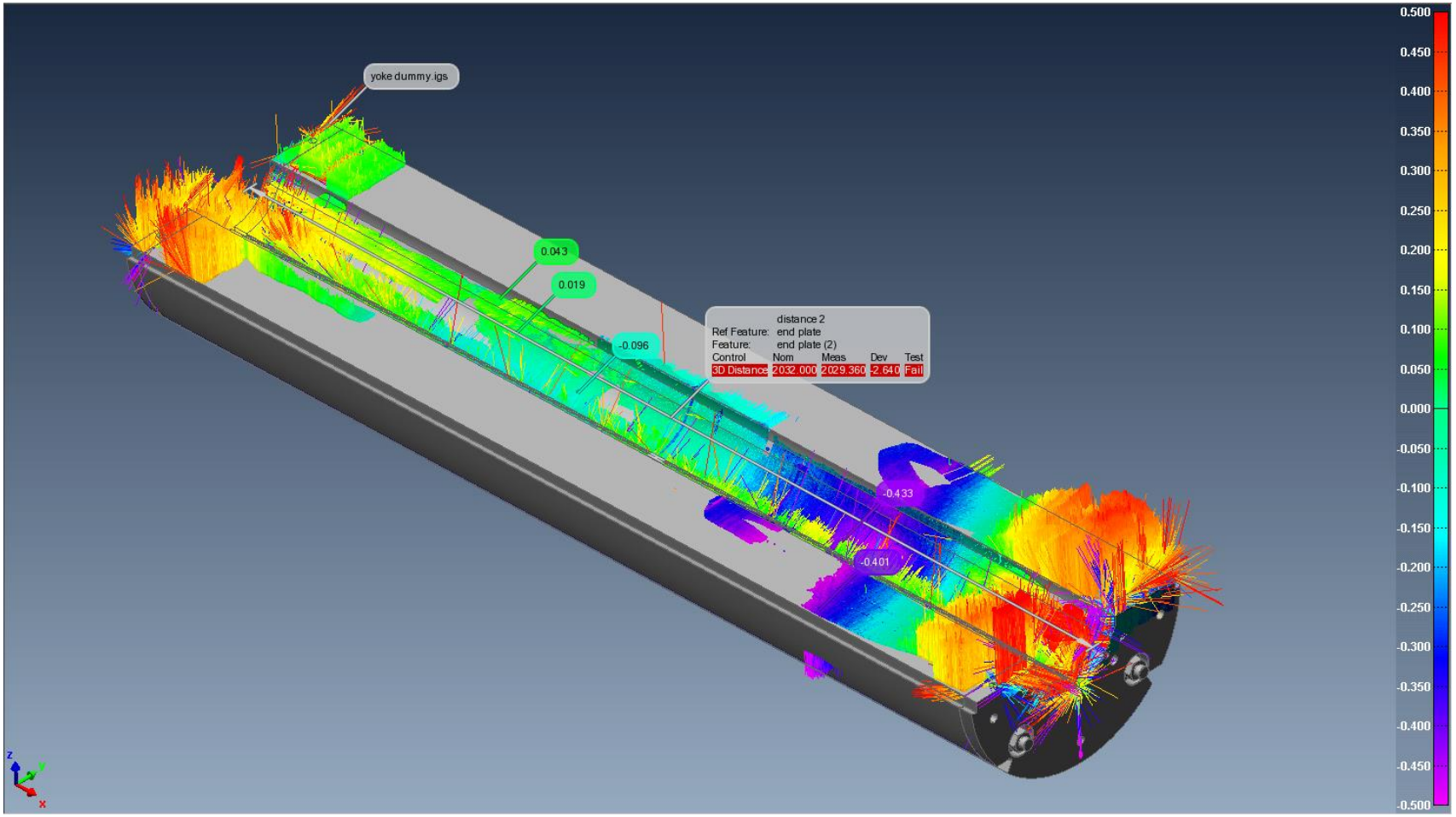
0.165

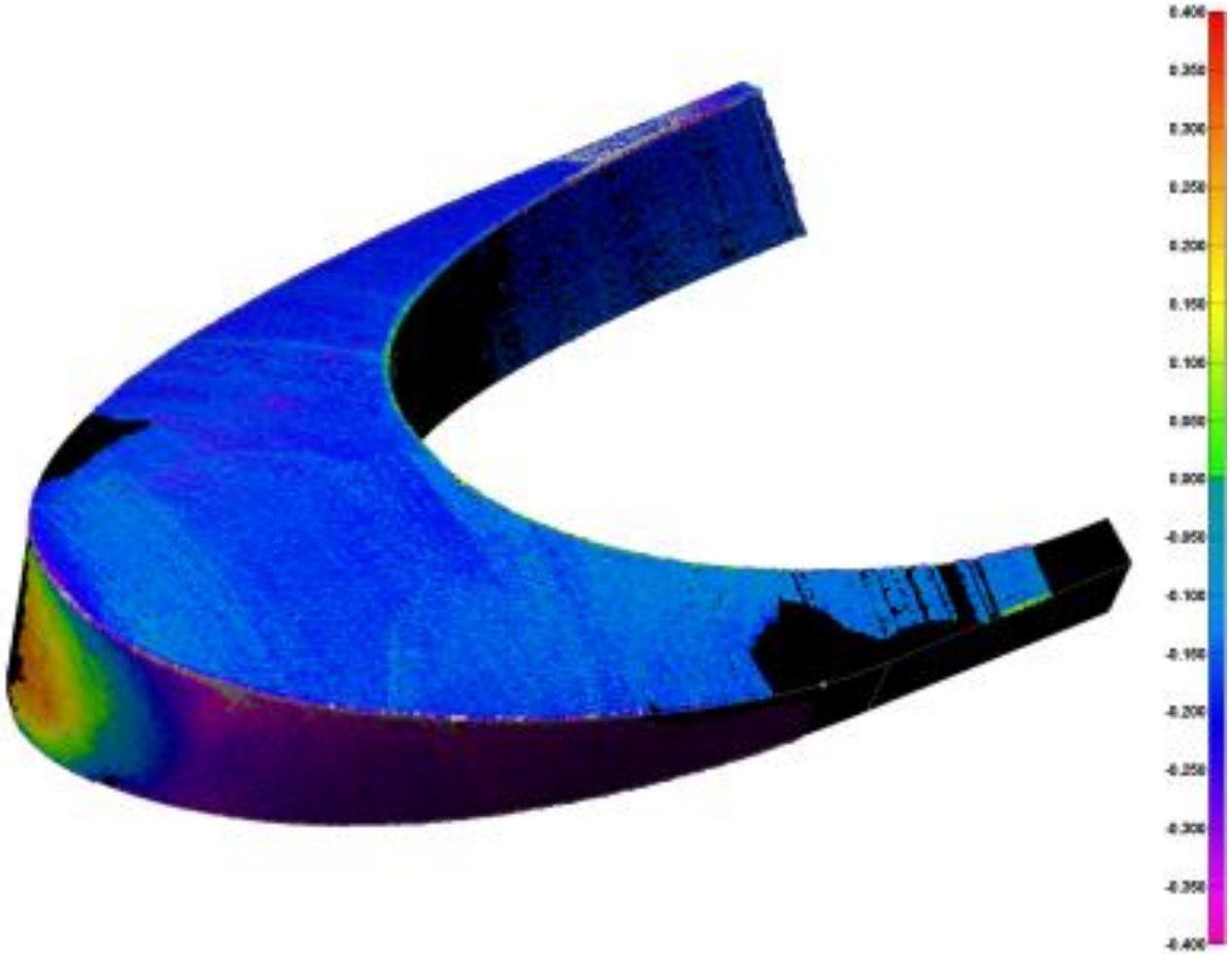
Interference between 105 & 101



Yoke cavity with proportional vectors – laser scanner



End spacer laser scanner



End spacer ball probe