16 T dipole in common coil configuration: mechanical design

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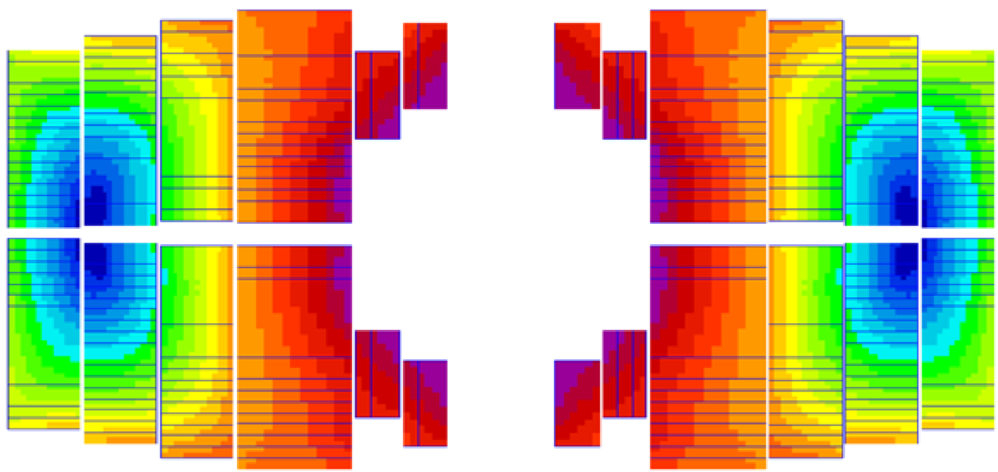
Common Coil scheme: Magnetic field

Ancillary coils

Main Coils

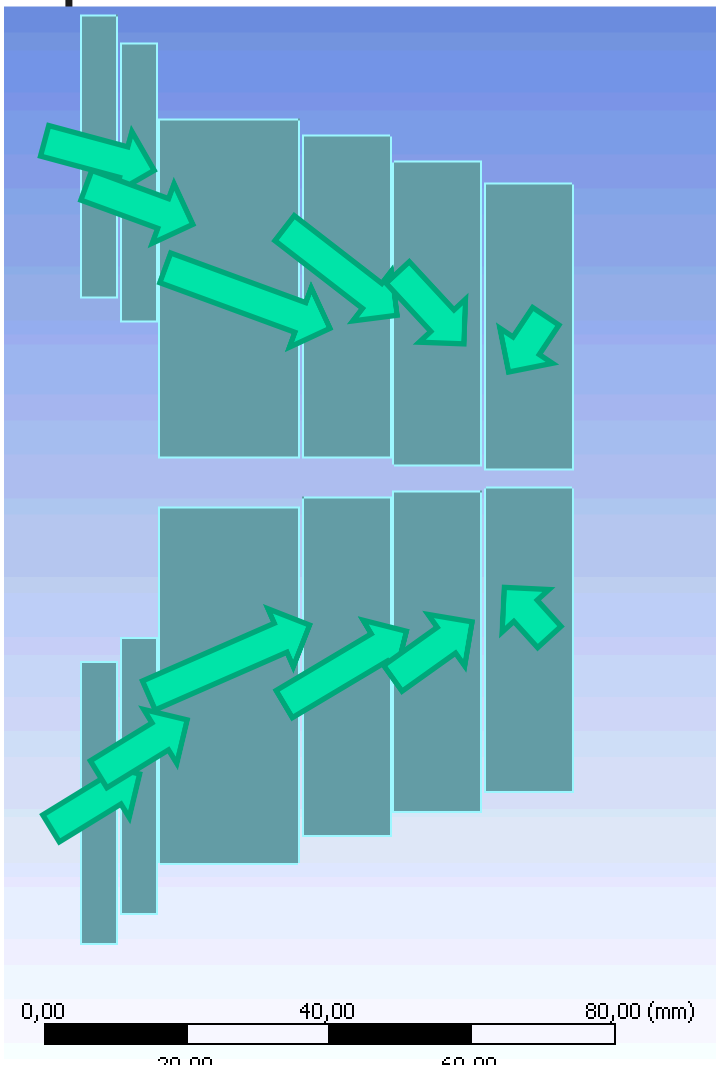
Main Coils

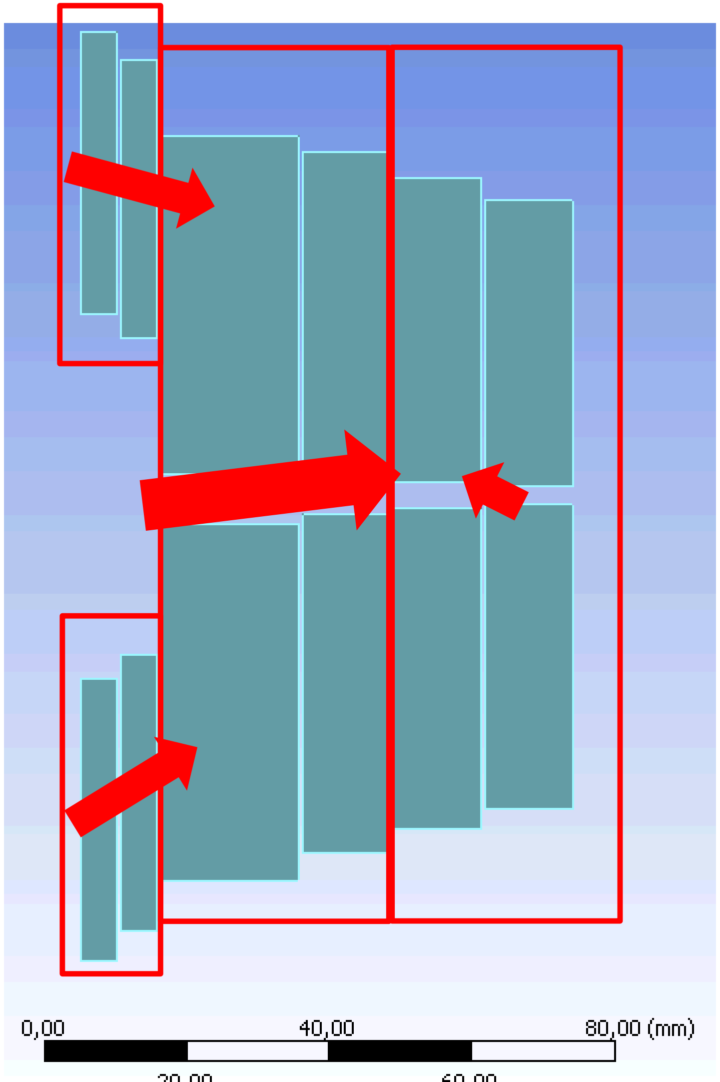


Notice orientation of cables

How forces are acting on these coils?

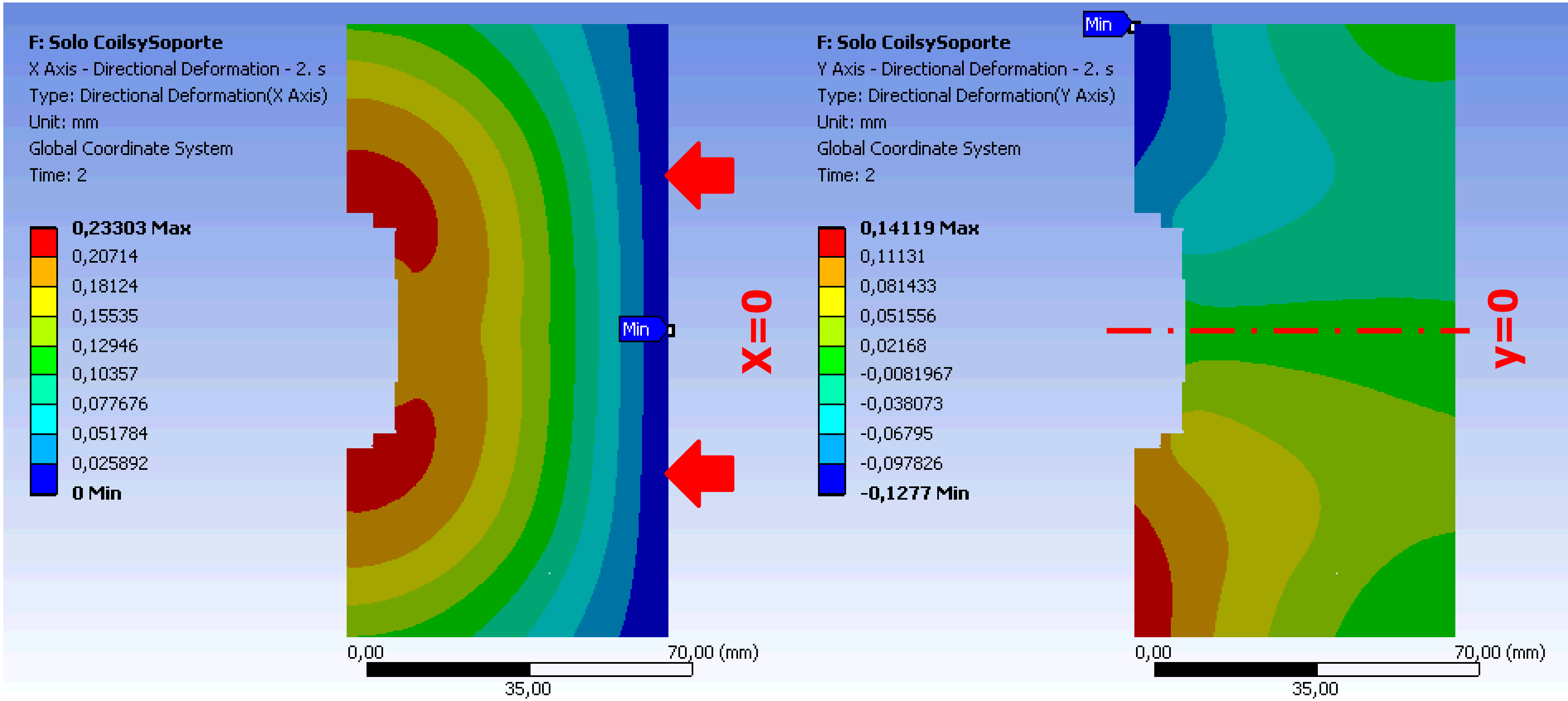
Common Coil scheme: Forces at coils





Common Coil scheme: Coils

JUST COILS: Horizontal movement constrained



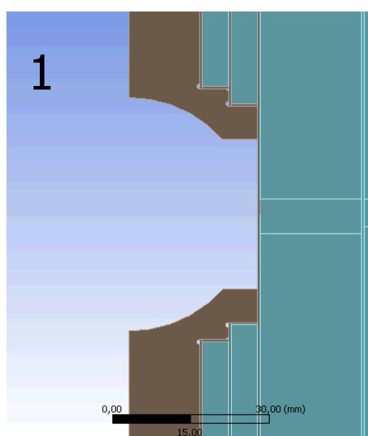
Horizontal force: +14,5 MN/m
Vertical force: +0,6 MN/m

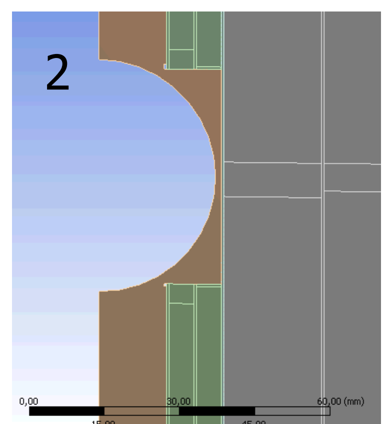
Horizontal displacement: +0,23 mm
Vertical displacement: -0,13 / +0,14 mm

Concept design: Inner support

- Two different approaches are being studied:
  1. Open structure at beam pipe:
     - Optimized magnetic design
     - Not horizontal support available for coil pre-stress at mean plane
  2. Closed structure at beam pipe
     - Coils should be moved from beam pipe to accomodate this closed structure
     - Stiffer support for higher horizontal pre-stress
     - It reduces horizontal displacements of the coils
     - Less efficiency from magnetic point of view -> More cable needed
     - Higher elastic energy in the coils due to prestress

Option 1 was evaluated in the past (see FCC week'17 slides)
Just a quick review now

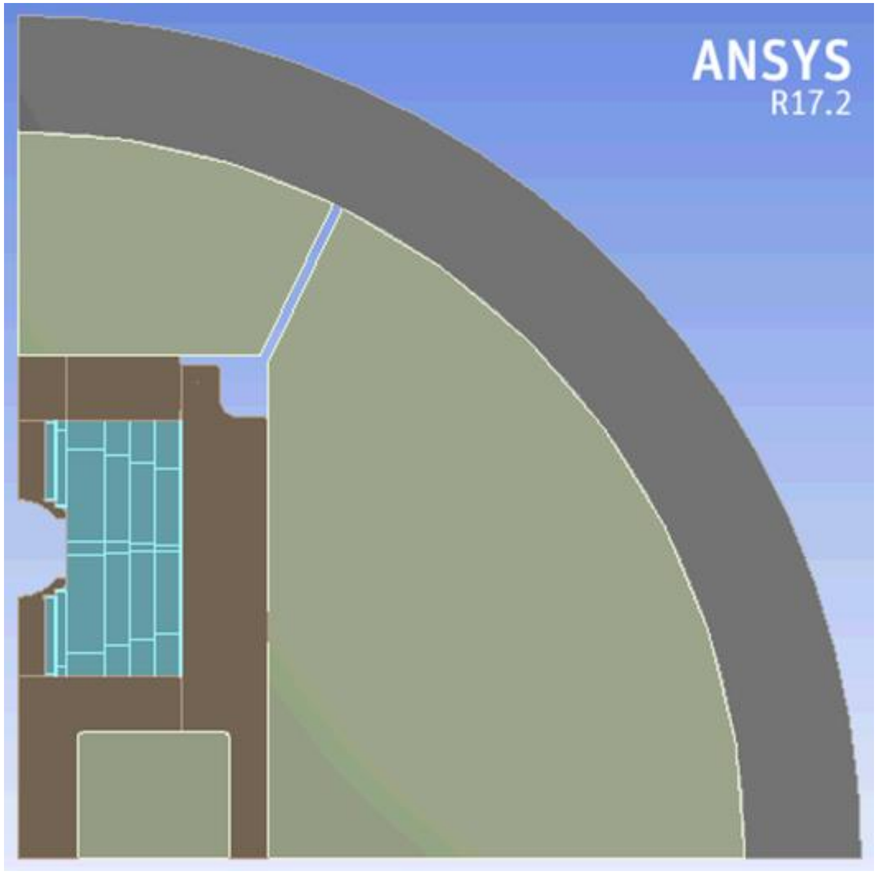




Option 2 will be shown here

Concept design: open support

- 40 mm stainless steel shell, small clearance for easy assembly.
- No prestress at warm
- Main coils are impregnated together with, but NONE of them are bonded to supporting structure

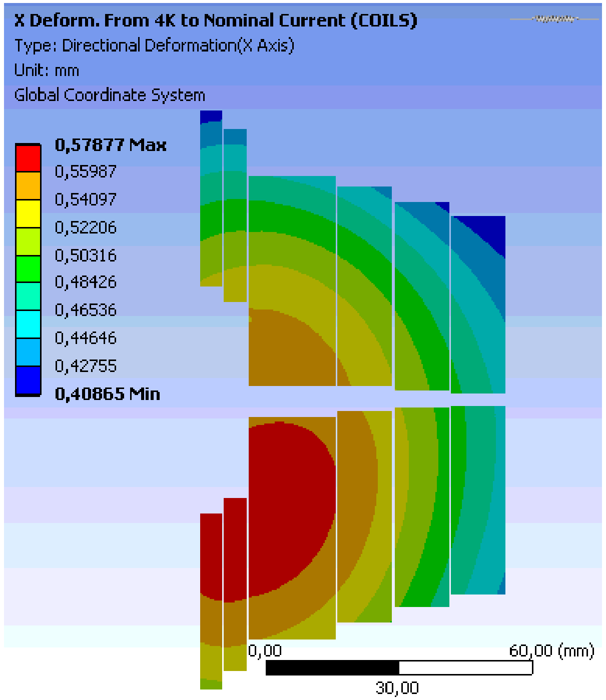


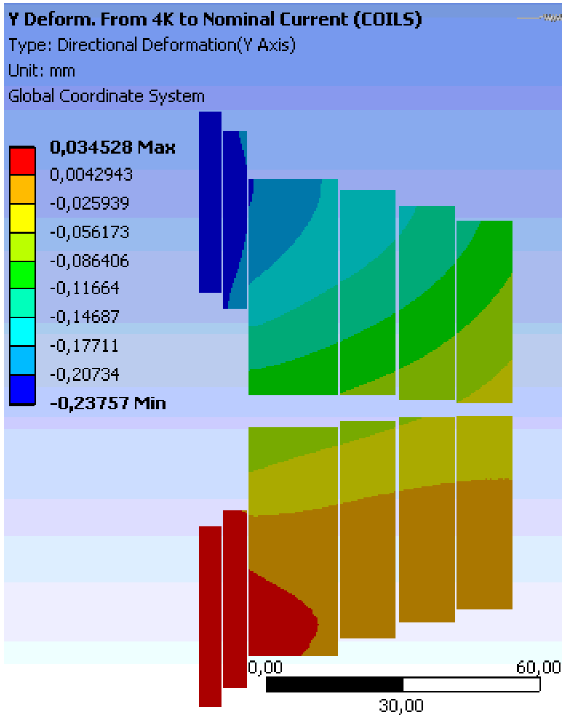
- It results in quite big displacements
- Contact pressure is not preserved at all surfaces

OPEN SUPPORT SUMMARY	
Displ. X COILS (mm)	0,58 / 0,40
Displ. Y COILS (mm)	0,03 / -0,23
σ_{VM} Support (MPa)	527
σ_{VM} Iron (MPa)	418
σ_1 Iron (MPa)	82

Coils displacements for open support design

- Total displacement **less than 0,6 mm in horizontal axis,**
  -0,07 mm in vertical (mean plane).
- Slight shape deformation (not parallel displacement along the coils)
  - Horizontal max/min (0,58-0,40=0,18 mm), vertical (0,03-(-0,23)=0,26mm)



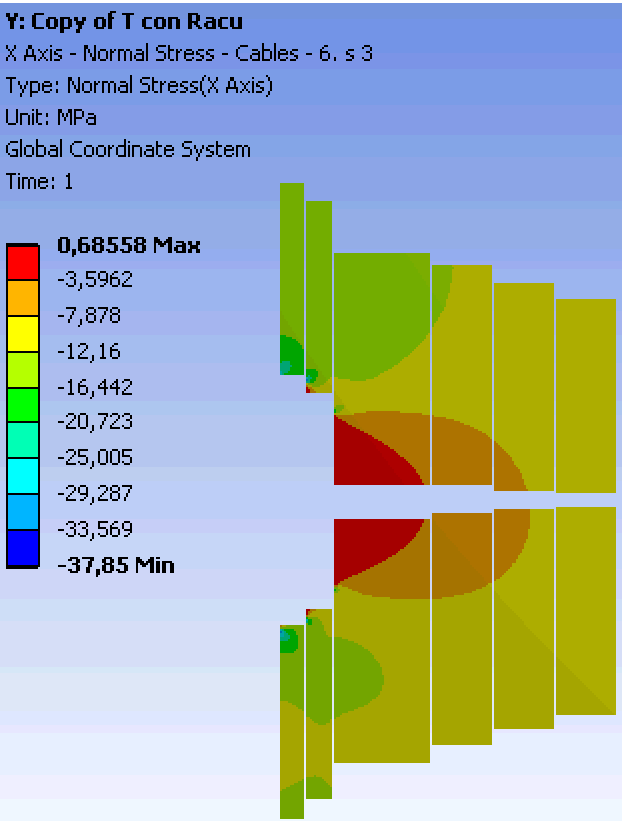


Coils RELATIVE displacement in mm:
horizontal (left) and vertical (right)

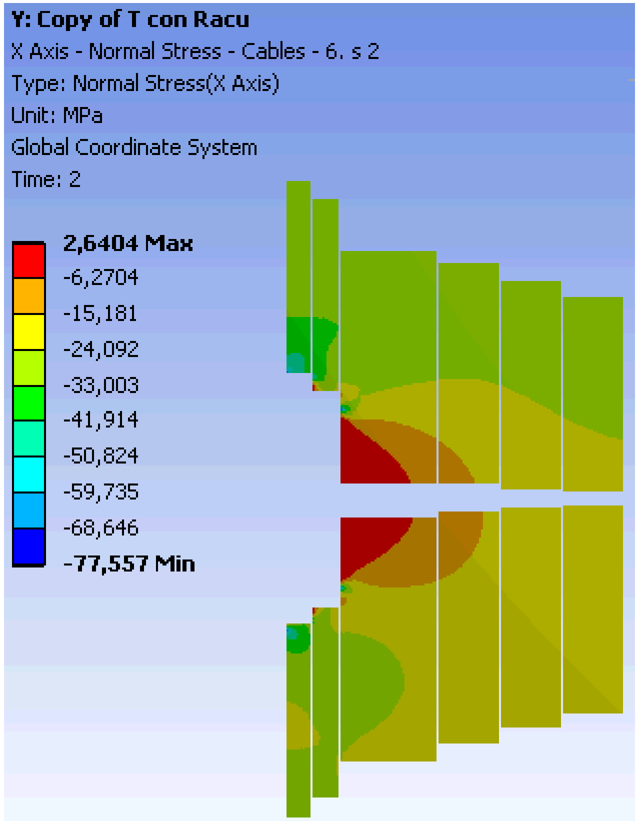
(displacement between cool down to nominal current)

Open support: Coils X stress

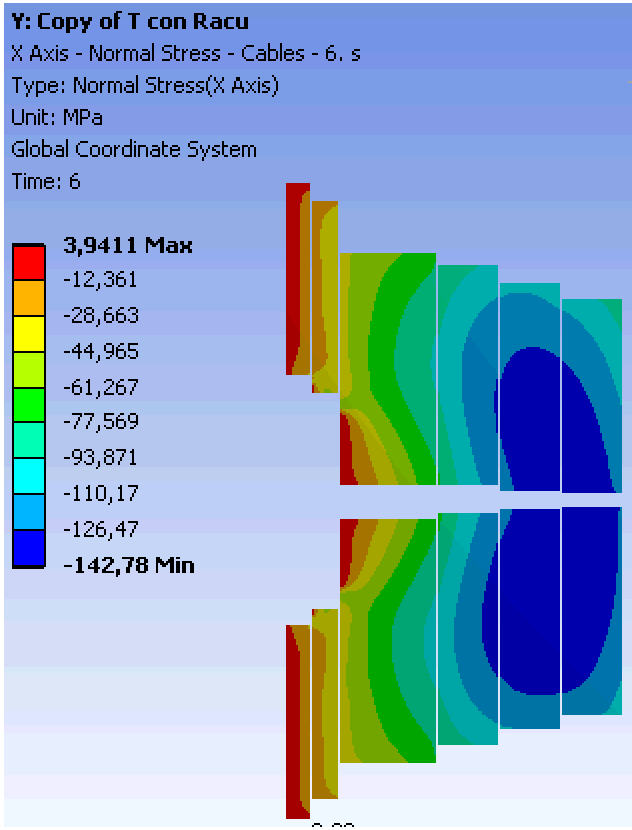
- “azimuthal” stress for Ancillary coils
- “radial” stress for main coils



Assembly
Peaks +0,7/-38 Mpa



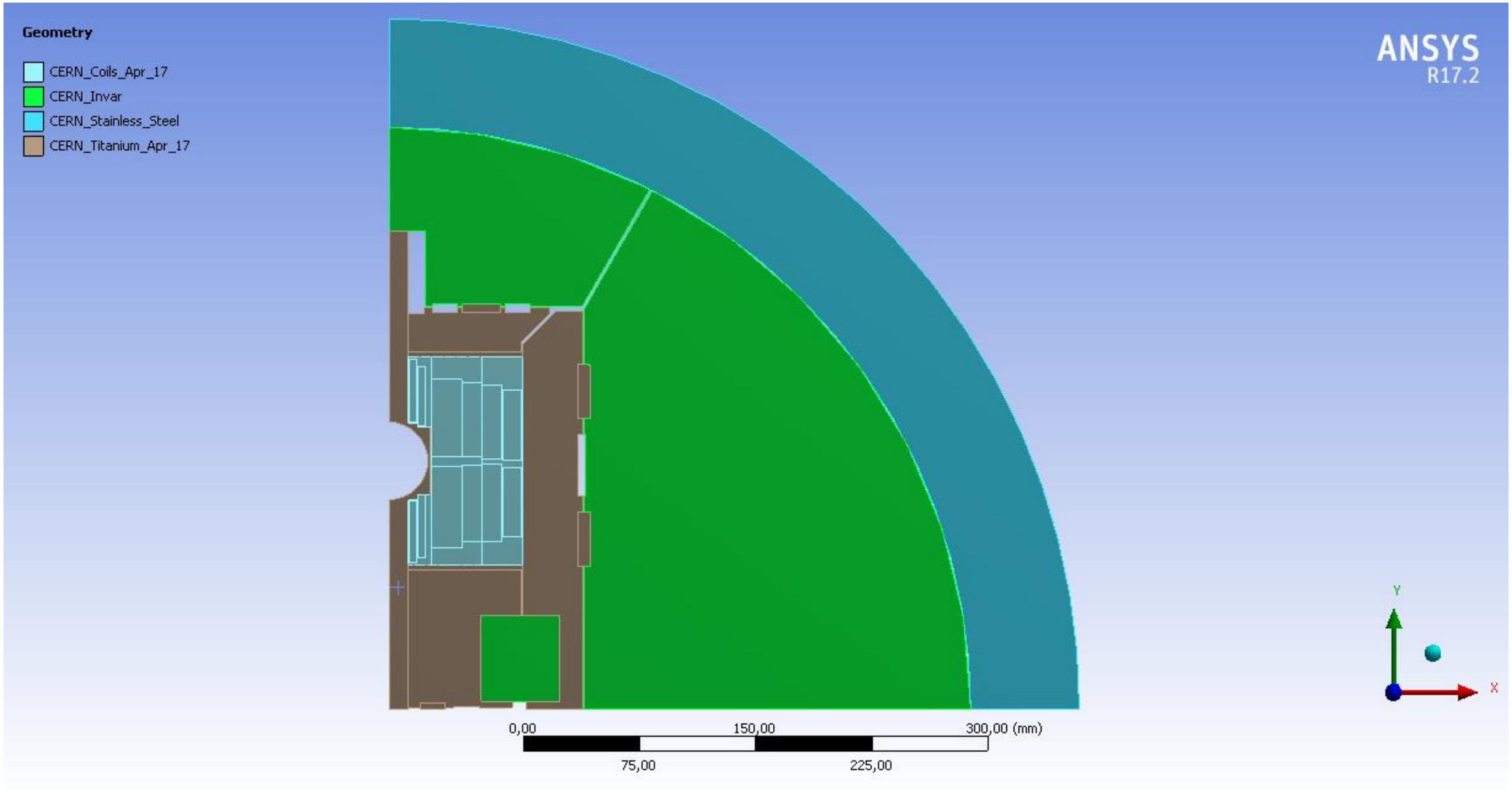
Cool down
Peaks +2,6/-78 MPa



16 T
Peak 4 MPa
"Max" 1/-140 Mpa

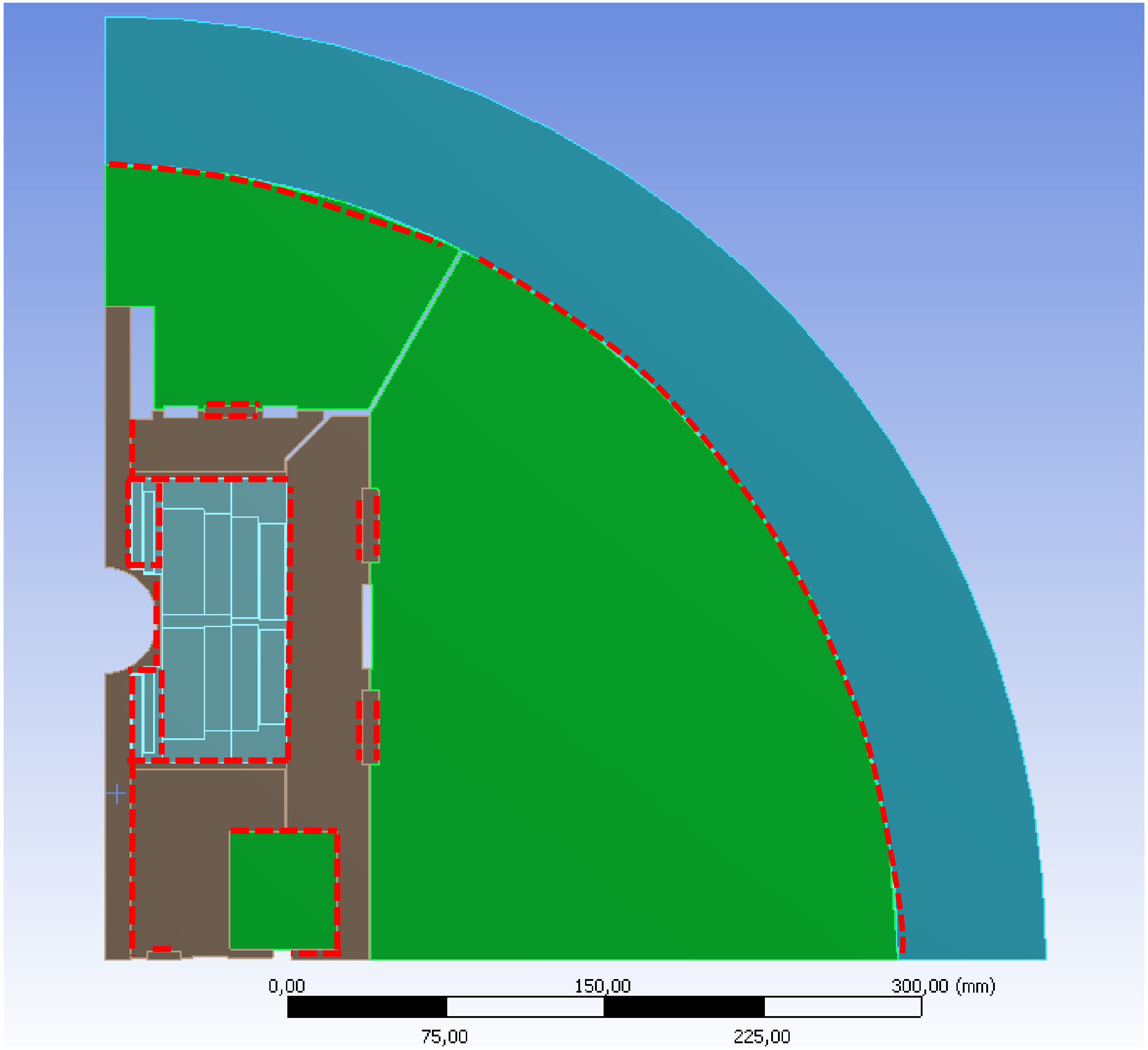
Concept design: CLOSED external support

- An outer shell of stainless steel (70 mm) holds the magnet against horizontal forces.
- Yoke is cut in 4 pieces. Invar to increase pre-stress. Magnetic simulation was made considering iron yoke, then changed to invar at structural analysis
- Main coils are impregnated together with, but NONE of them are bonded to supporting structure



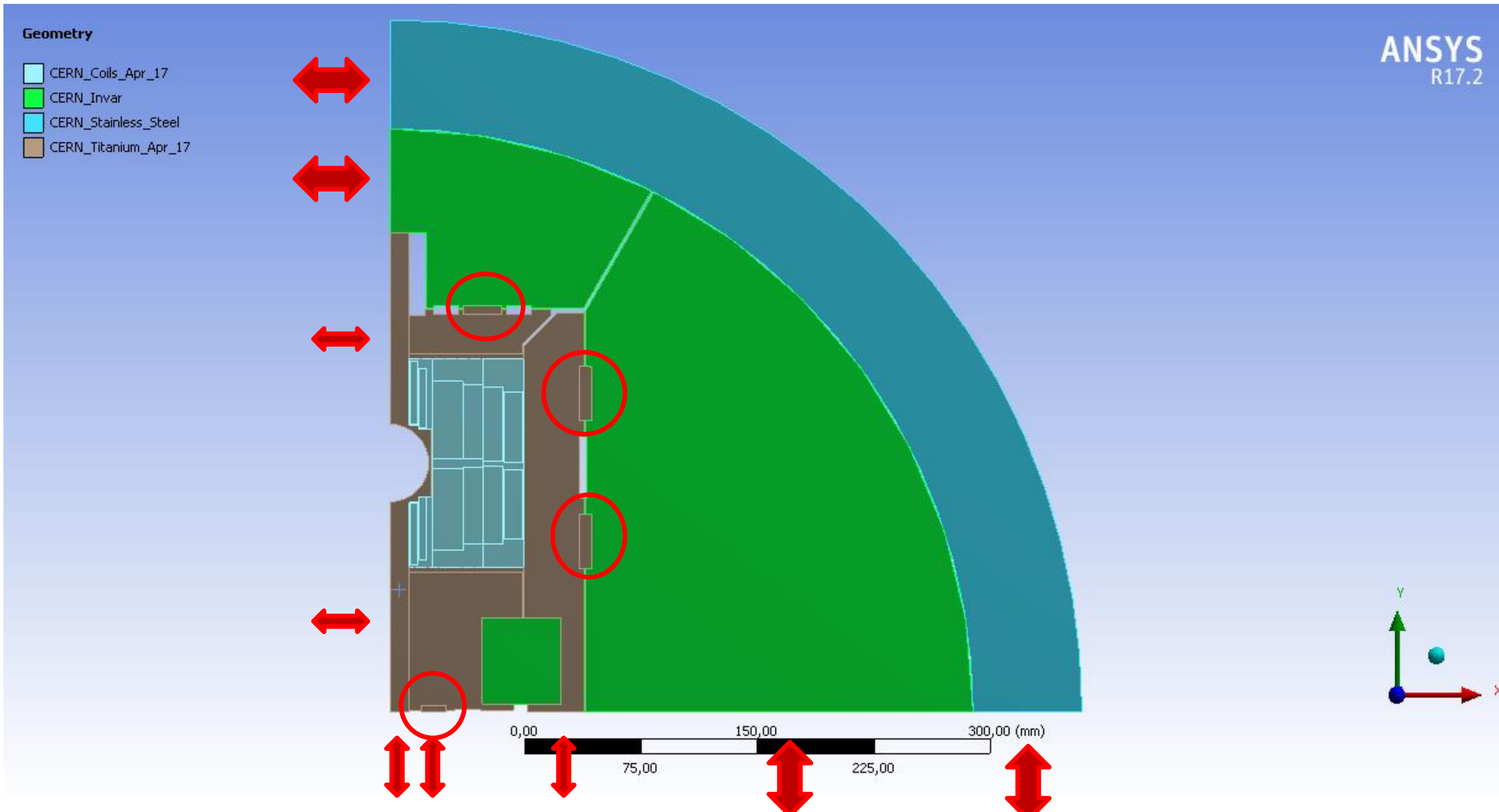
Concept design: external support

Frictional
c.f= 0,2



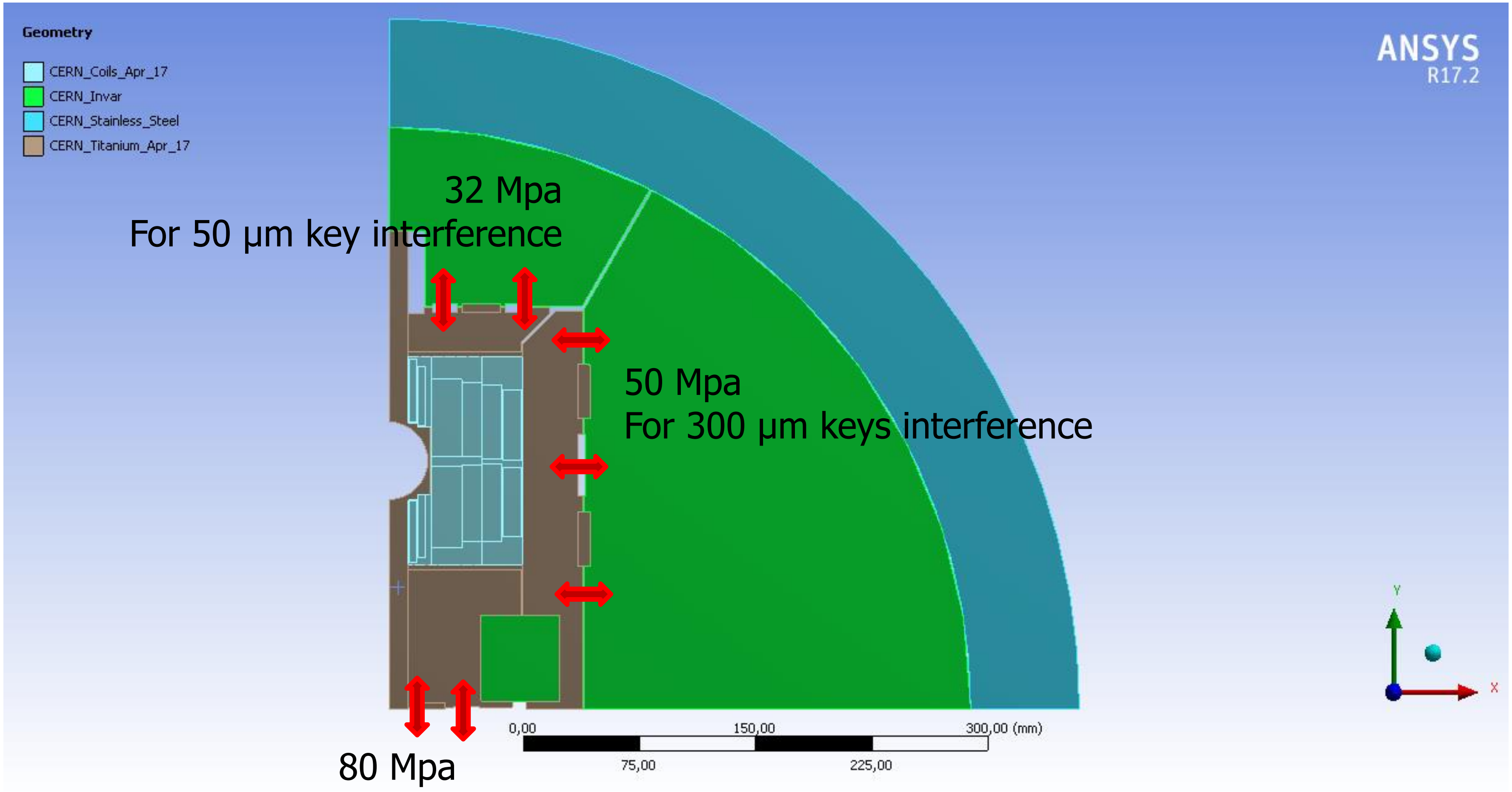
Concept design: external support

- TWO keys are used for horizontal prestress and TWO keys for vertical prestress
- Horizontal and Vertical Symmetries



Assembly

- TWO keys are used for horizontal prestress and TWO keys for vertical prestress
- Horizontal and Vertical Symmetries

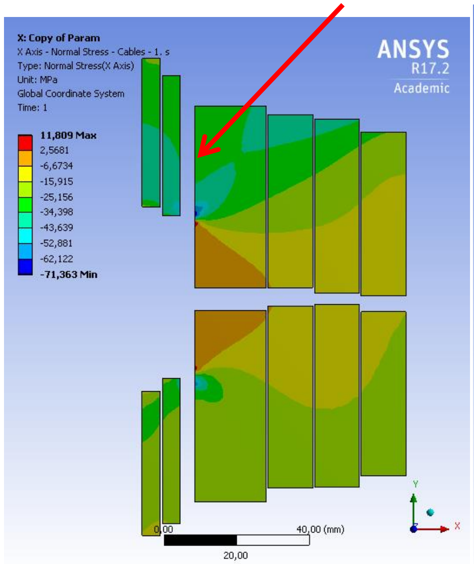


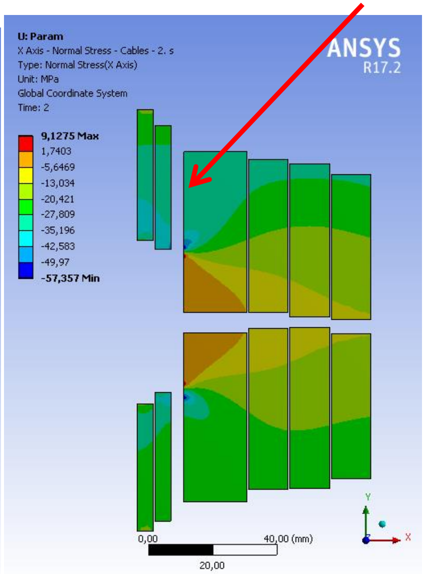
80 Mpa
For 50 µm key interference
(Symmetric)

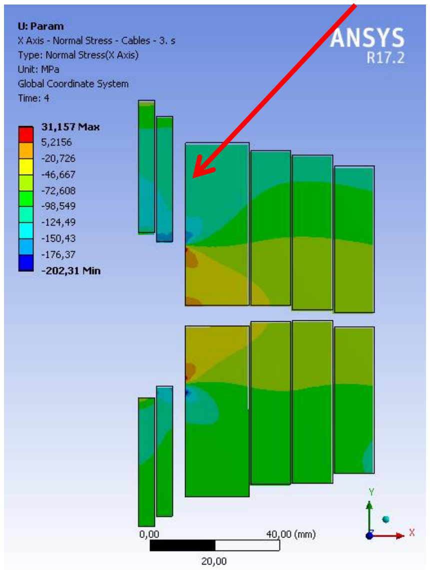
Coils X stress

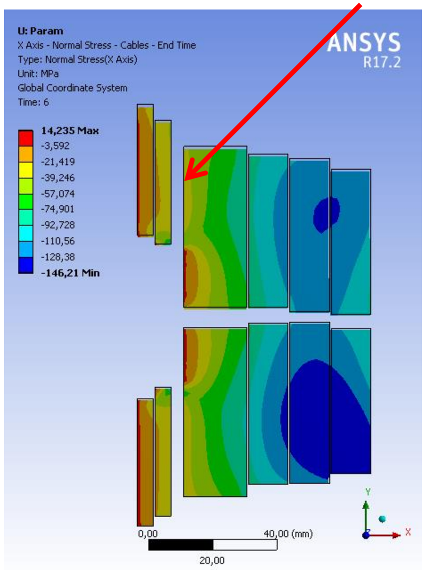
- “azimuthal” stress for Ancillary coils
- “radial” stress for main coils

Contact pressure *-35 MPa* *-28 MPa* *-120 MPa* *-25 MPa*









Assembly
Peaks +11/-71 Mpa

Keys in
Peaks +9/-57 Mpa

Cool down
Peaks +31/-202 MPa

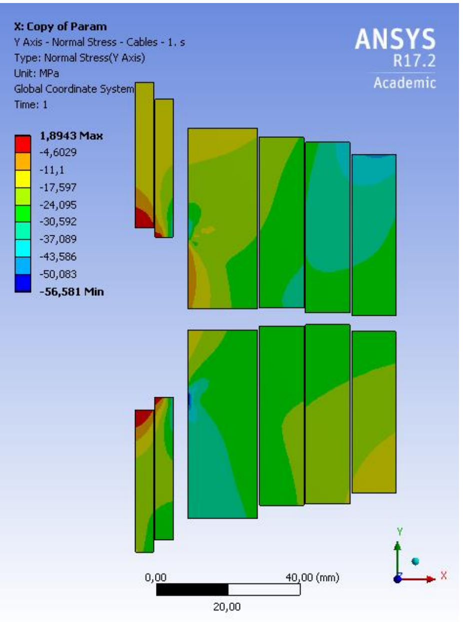
16 T
Peaks +14/-146 MPa

Peaks coming from stress concentracion at center pole

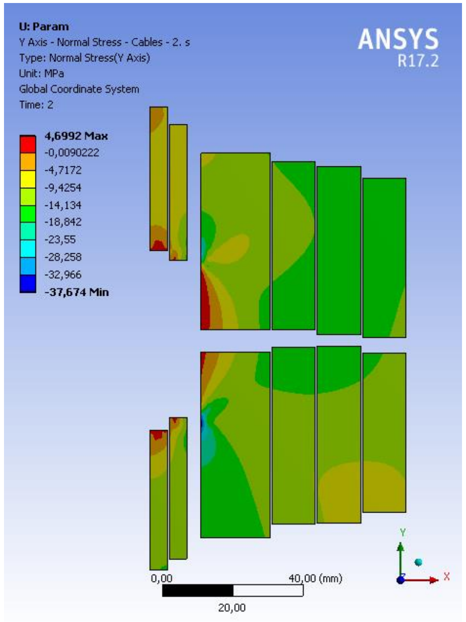
For open support design: -38,-,-78,-140 MPa

Coils Y stress

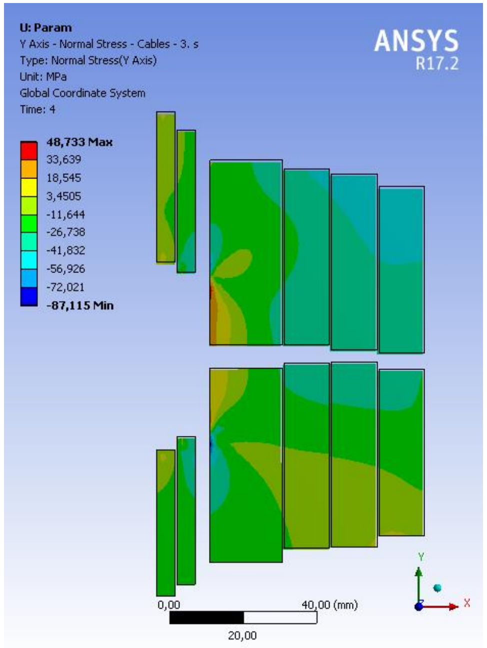
- “azimuthal” stress for Ancillary coils
- “radial” stress for main coils



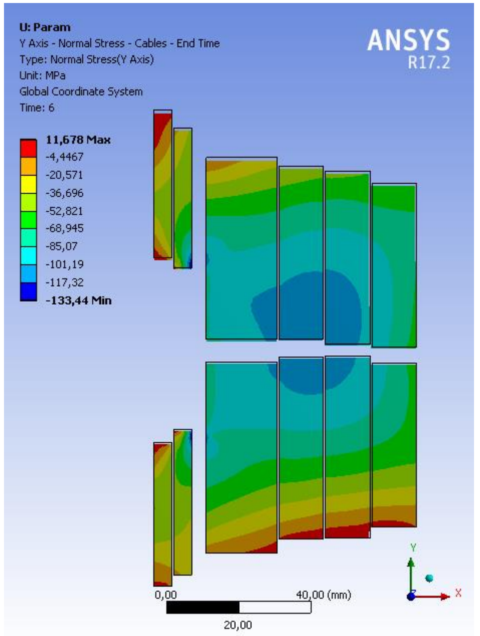
Assembly
Peaks +1/-56 Mpa



Keys in
Peaks +4/-37 Mpa



Cool down
Peaks +48/-87 MPa

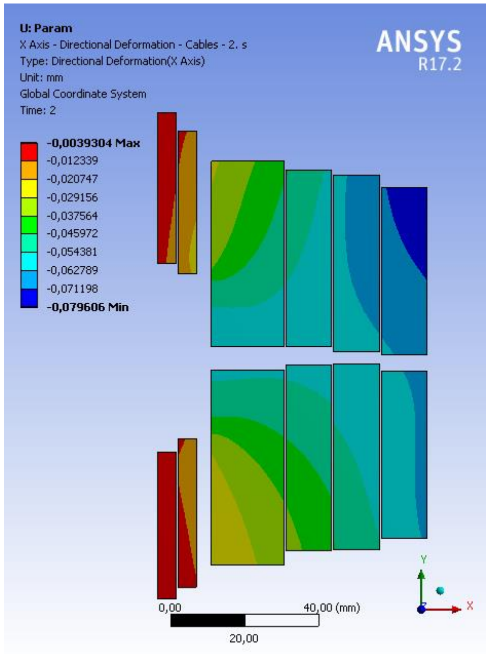


16 T
Peaks +11/-133 MPa

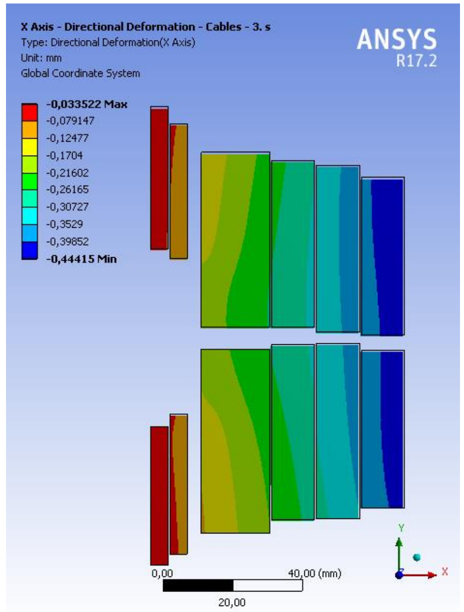
Peaks coming from stress concentracion at center pole

For open support design: -20,-,-66,-155 MPa

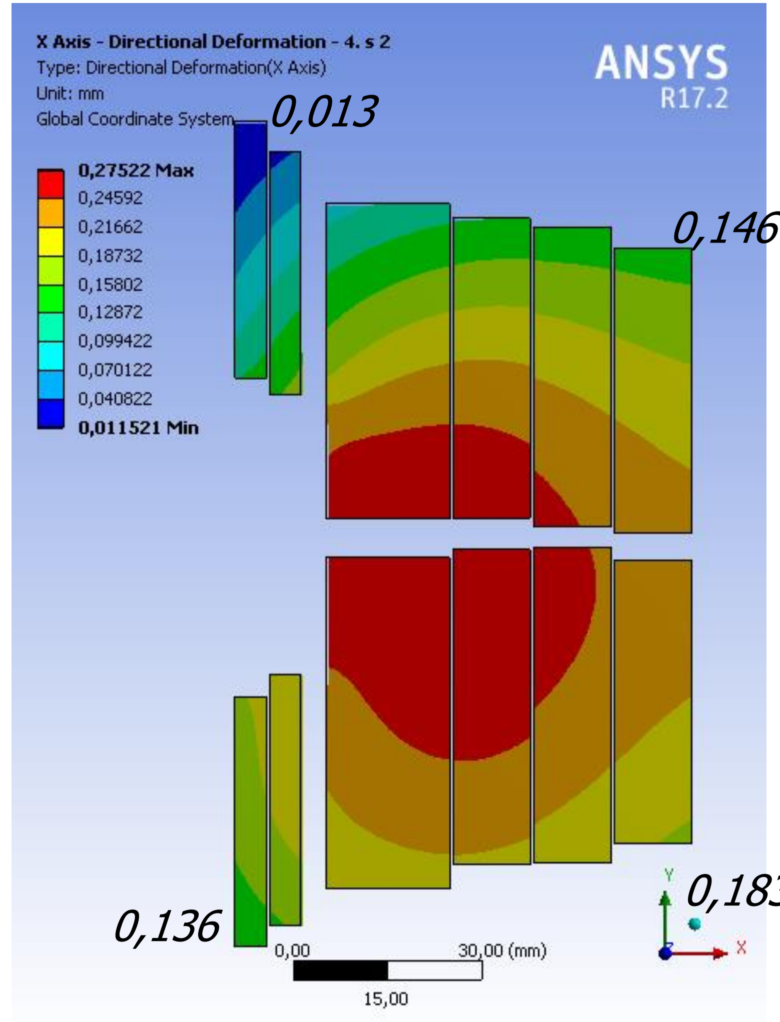
Coils X displacements



Assembly
Max +0/-0,079 mm

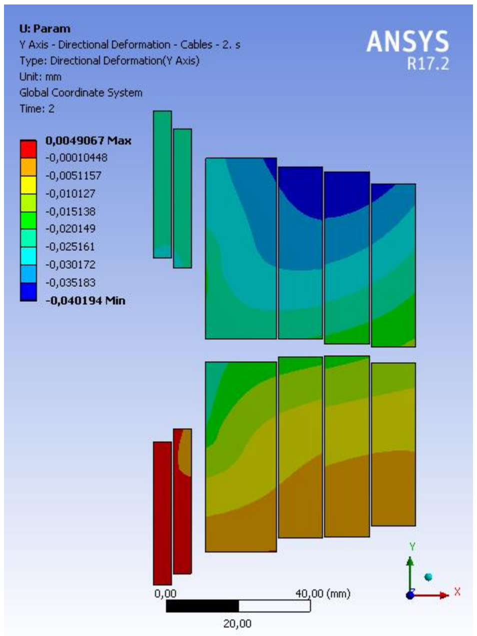


From Assembly to Cool down
Max -0,034/-0,44 mm

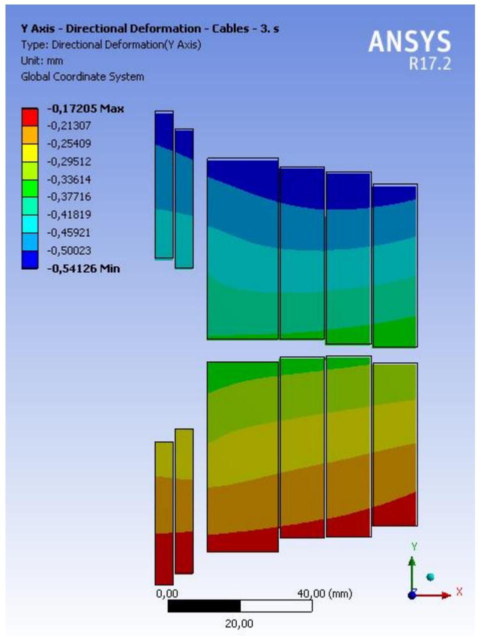


From 0 T to 16 T
Max +0,275/+0,011 mm

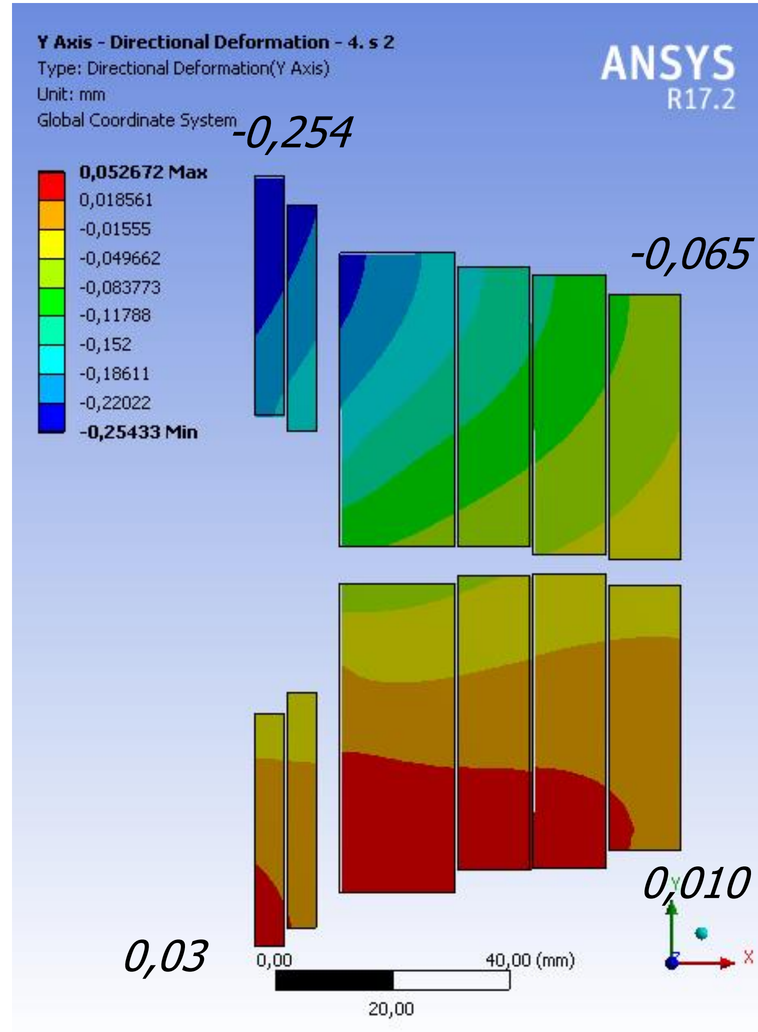
Coils Y displacements



Assembly
Max +0/-0,040 mm



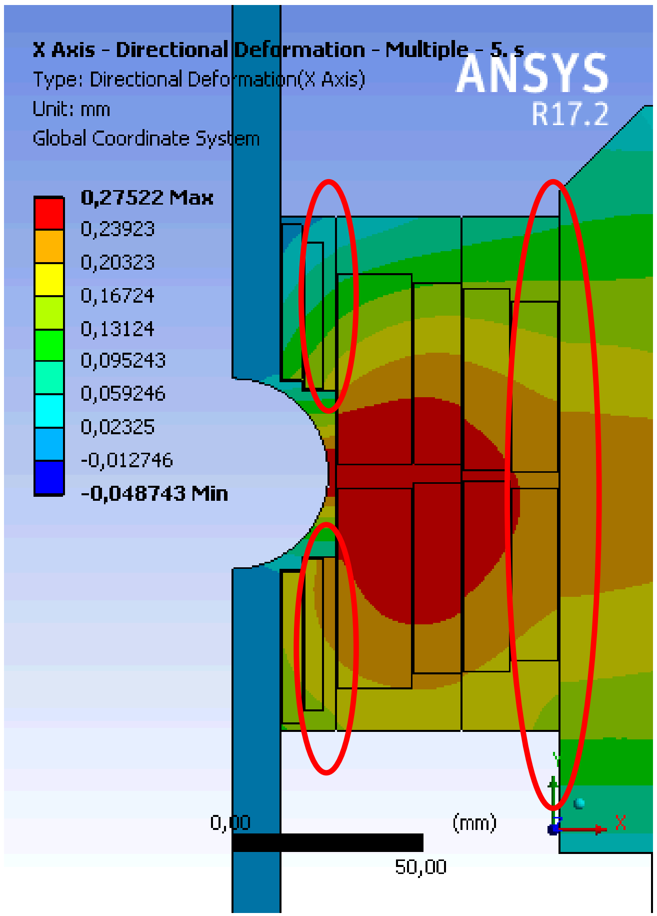
From Assembly to Cool down
Max -0,541/-0,172 mm



From 0 T to 16 T
Max +0,053/-0,254 mm

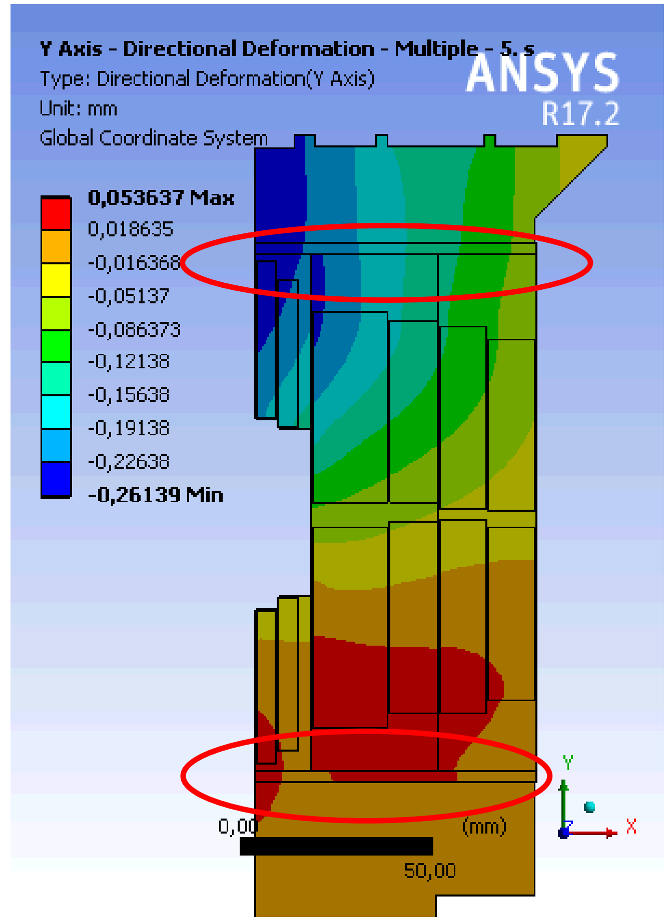
Blocks: from 0T to 16 T

X Displacement



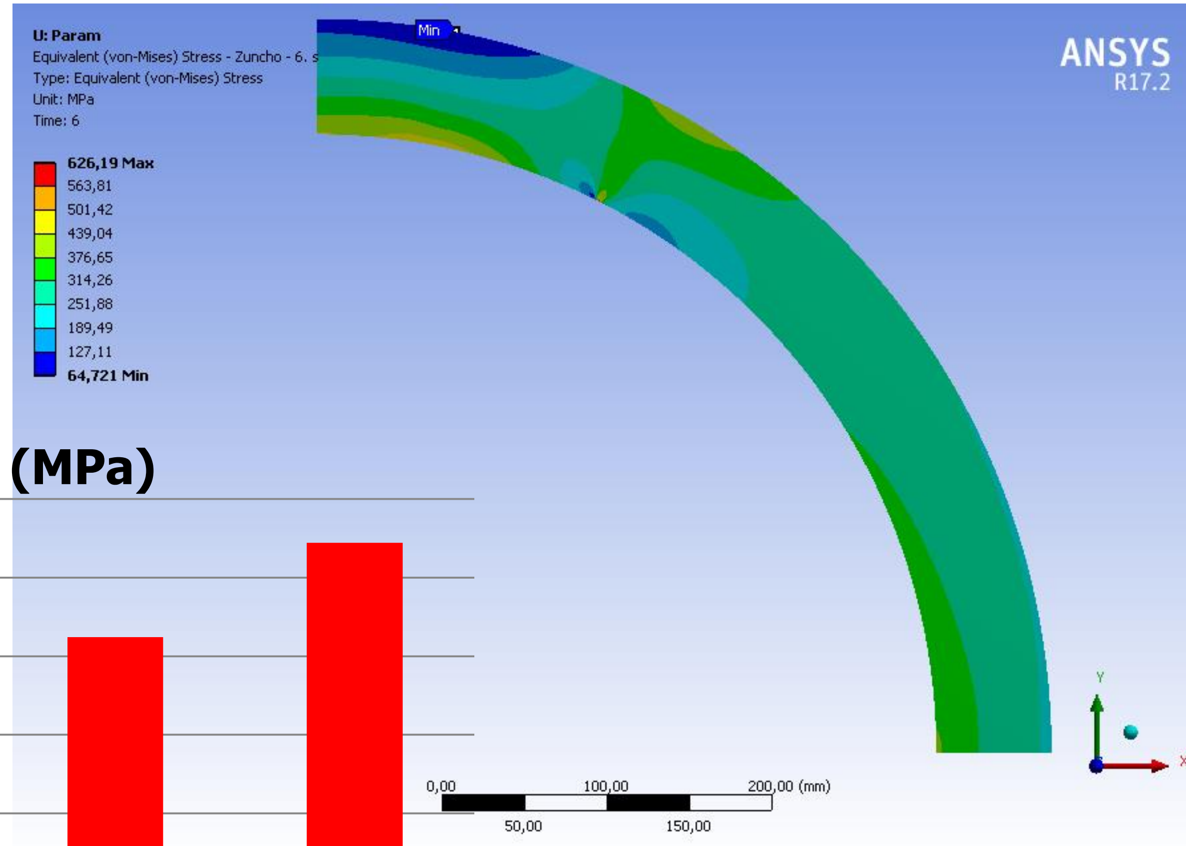
Horizontal contact everywhere in blocks

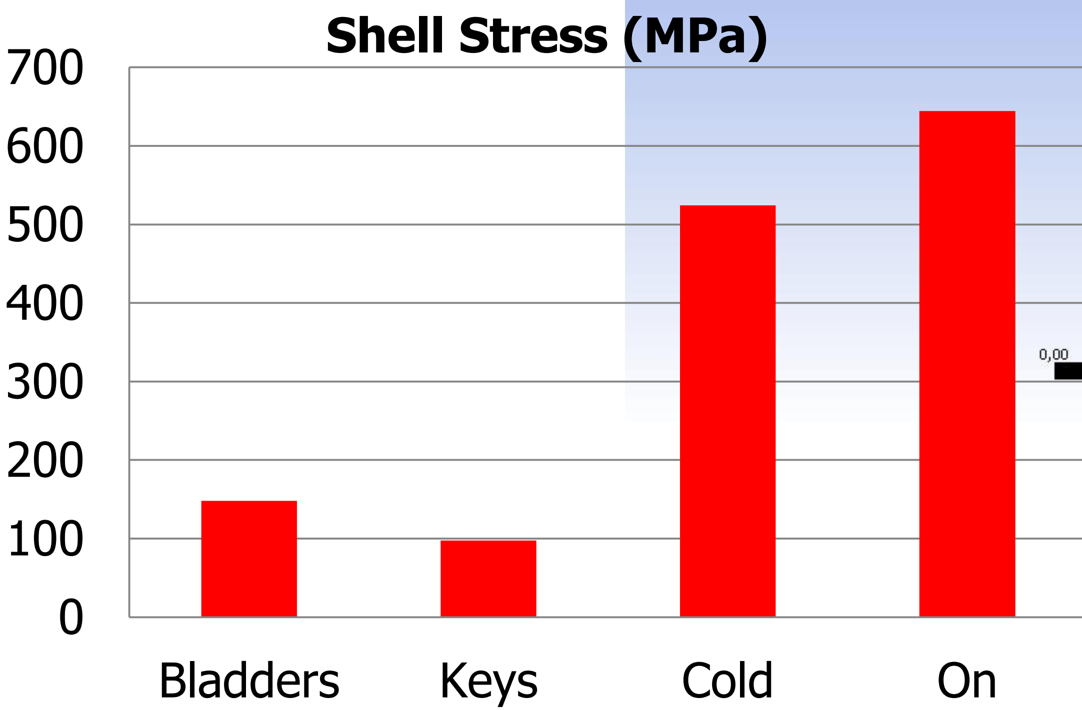
Y Displacement



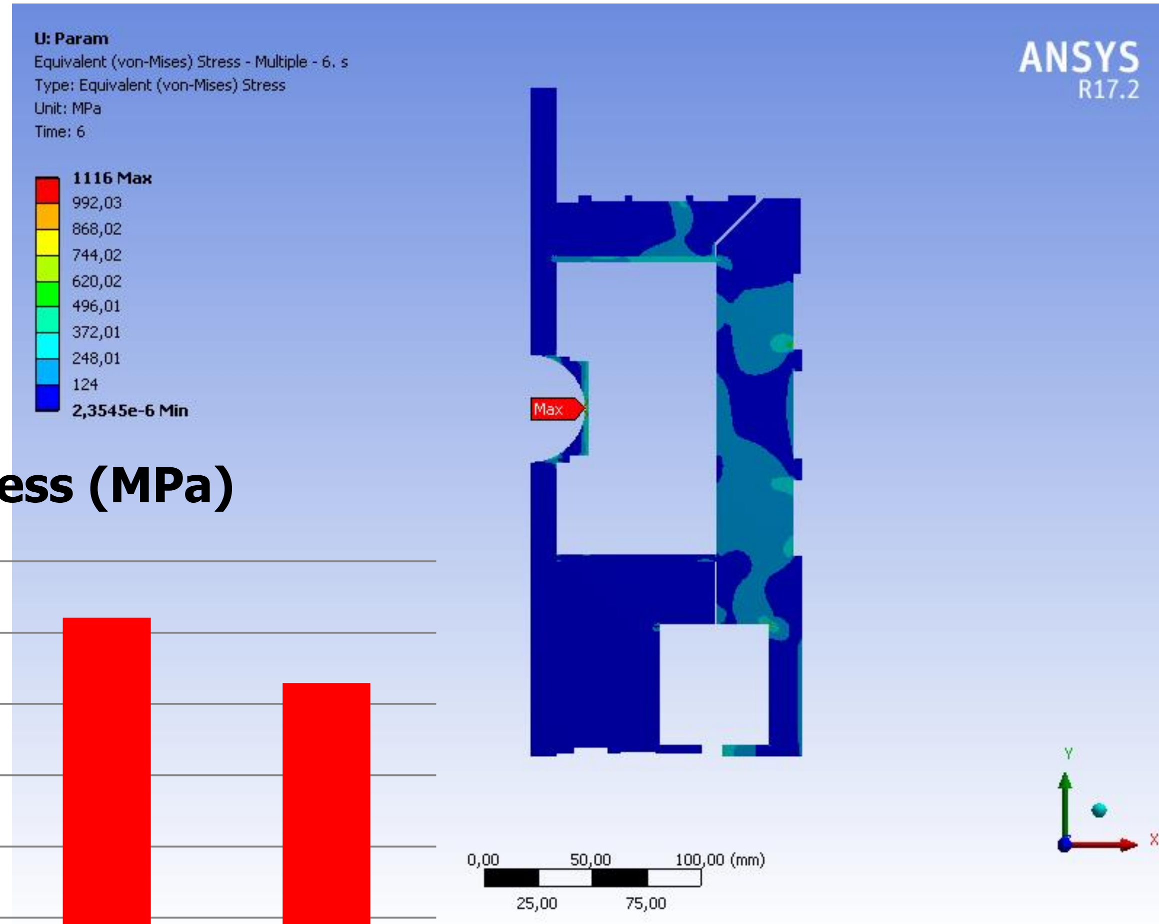
Just small areas lose vertical contact at blocks

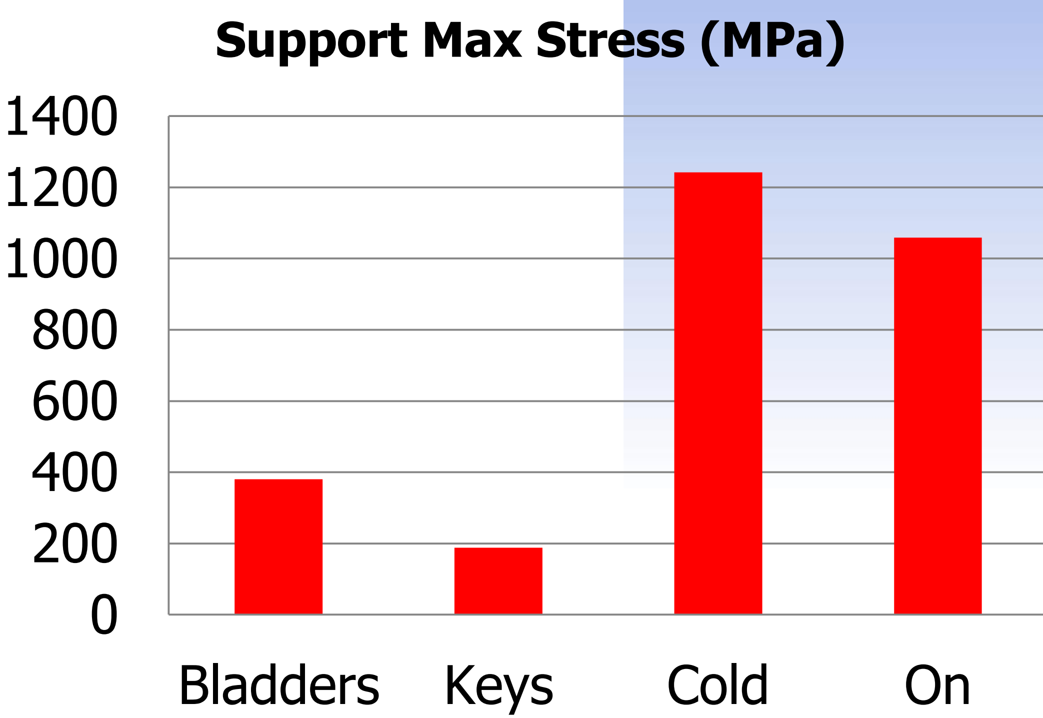
Shell: Stainless Steel



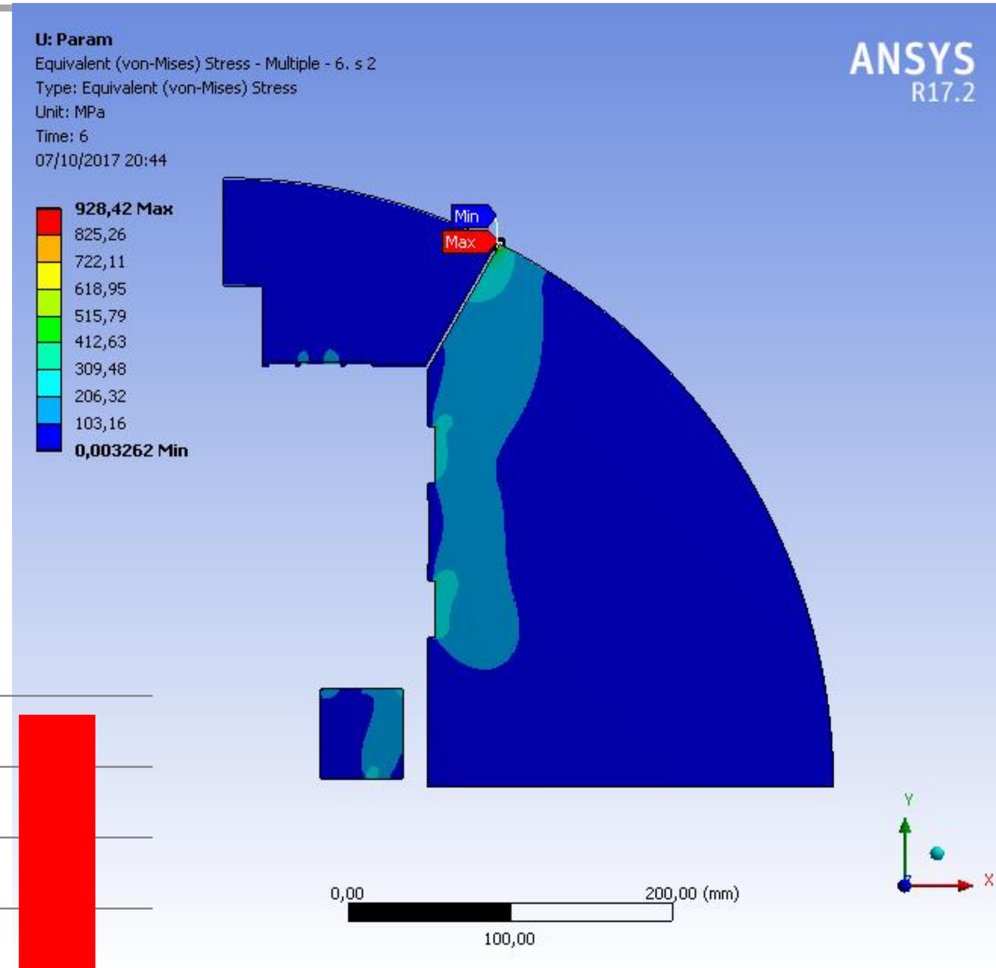


Supports: Titanium

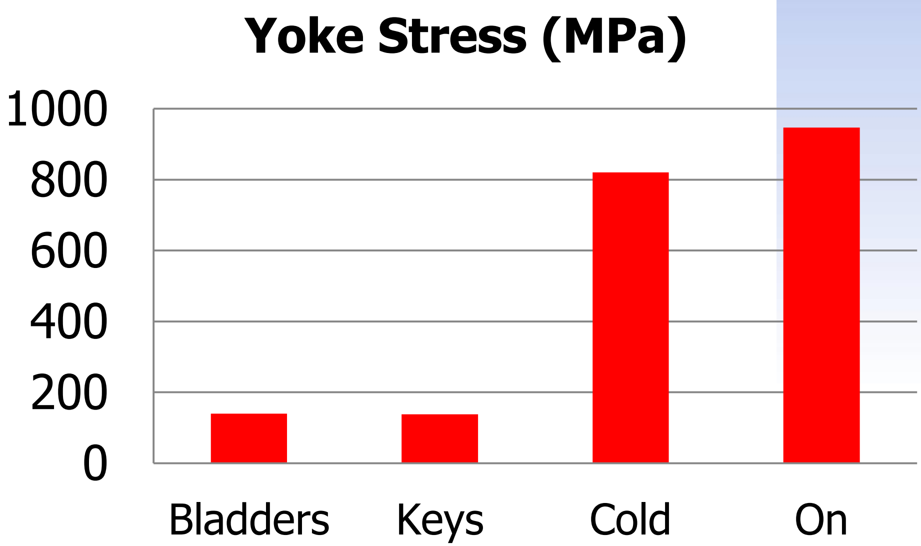




Yoke: Invar



U: Param
Equivalent (von-Mises) Stress - Multiple - 6. s 2
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 6
07/10/2017 20:44
928,42 Max
825,26
722,11
618,95
515,79
412,63
309,48
206,32
103,16
0,003262 Min
ANSYS
R17.2
Min
Max
0,00
200,00 (mm)
100,00
Y
X



Yoke Stress (MPa)
1000
800
600
400
200
0
Bladders
Keys
Cold
On

Conclusions

OPEN SUPPORT SUMMARY (16T)	
Displ. X COILS (mm)	0,58 / 0,40
Displ. Y COILS (mm)	0,03 / -0,23
σ_{VM} Support (MPa)	527
σ_{VM} Iron (MPa)	418

CLOSED SUPPORT SUMMARY (16T)	
Displ. X COILS (mm)	0,275 / 0,11
Displ. Y COILS (mm)	0,52 / -0,25
σ_{VM} Support (MPa)	1059
σ_{VM} Yoke (MPa)	946

Conclusions

- A closed inner support provide much more prestress, which could result in quite similar situation as a infinite rigid support
- Two vertical keys are needed in order to spread vertical preload between ancillary coils
- Delivery of such amount of prestress could lead to a degradation of the cable based on the specifications
- Even when coils are under compression at both directions, separation can result on some areas on the cable because the distribution of magnetic forces

- The open support concept will result in larger displacements of the coil and shape deformation of the coil
- Sliding of the coil will occur with no pressure force

Thank you for your attention