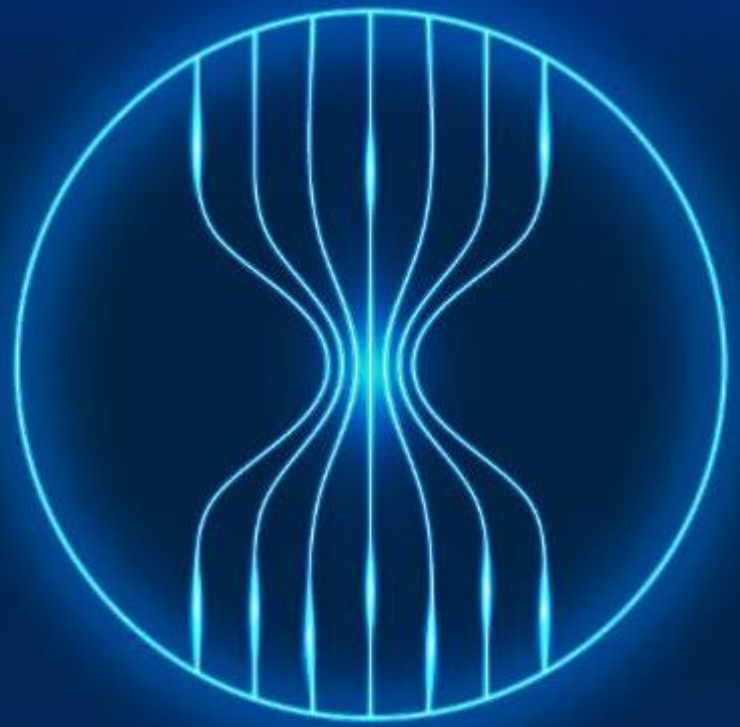

HFM

High Field Magnets

Progress on ISAAC

J. García Matos, C. Martins, F. Toral (CIEMAT)
J.C. Pérez (CERN)

Outline

- ISAAC goals & constraints (reminder)
- 2D Design update
  - 34 mm aperture
  - 50 mm aperture
- 3D Design (34mm aperture)
  - Magnetic - Maxwell
  - Mechanical – Ansys
- Conclusions

Outline

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ISAAC goals & constraints (reminder)

- **ISAAC**: **I**nvestigating **S**uperconducting **A**ssembly to **A**ddress **C**ommon coil mechanics
- Main goal: learn for the 14 T model with **existing coils**, mostly on **mechanics**
  - Existing RMC coils made at CERN with MQXF strand are selected
  - Mechanics & assembly as simple as possible
  - Provide ≈14 T in the aperture (100% load)
  - Decrease vertical Lorentz force F_y to achieve low vertical preload: free horizontal movement when coils are energized, without friction
- Assembly with **bladder and keys**, slight **preload** just to keep contact between parts
- **Aluminium shell** also contributes to hold the forces
- Goal: To have a horizontal **coil displacement** due to the EMF **below 0.5 mm** to:
  - Reduce the impact on field quality (0.5 mm -> 1% less field in the aperture)
  - Reduce the possibility of sudden coil movements (to avoid quenches)

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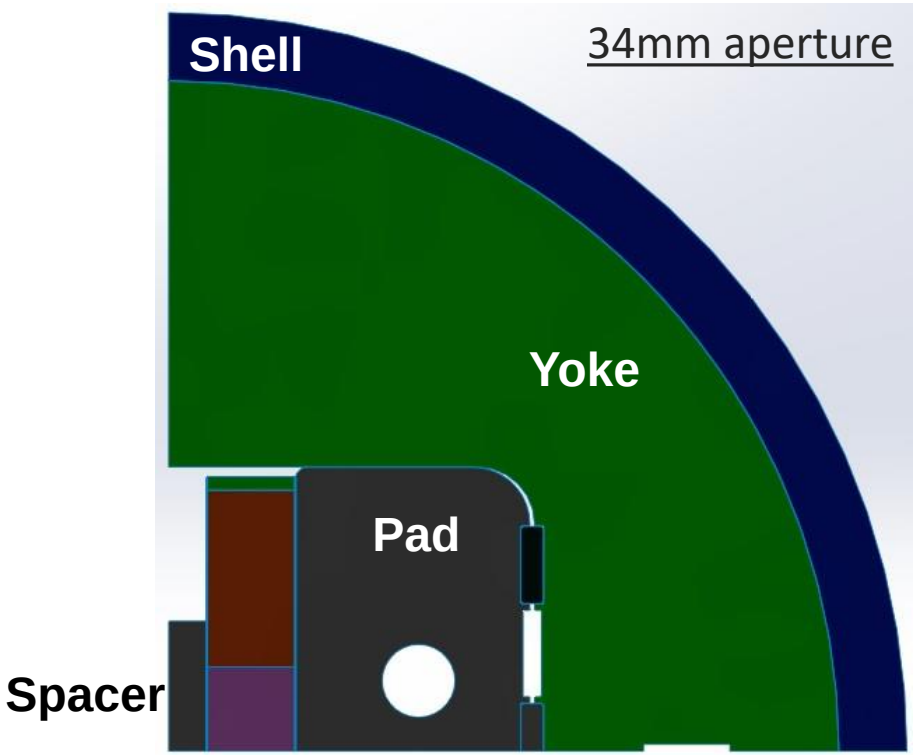
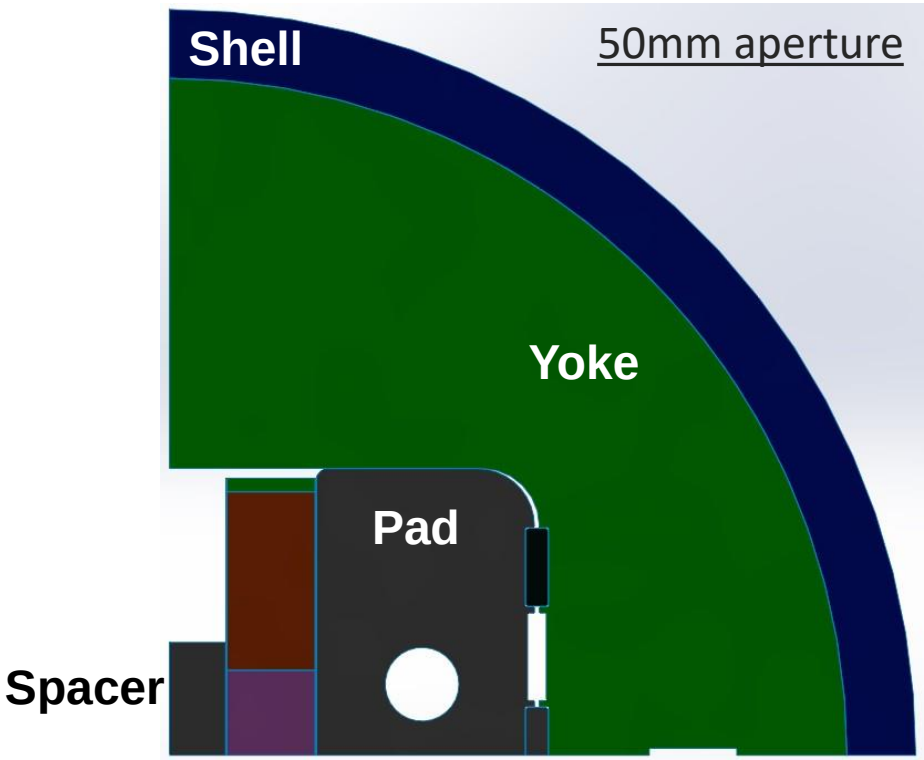
2D Design update

- One Ø30 mm Rod per quadrant
- Pad width: 30 mm @ both sides of the rod with 50 mm aperture
- Fixed Yoke and Shell for different apertures (34 mm & 50 mm): Only Pad and Spacer change
- **Shell** dimensions: **Ø Outer**: **650 mm**. **Thickness**: **30 mm** (Ø Inner: 590 mm)
- **Iron** components **EMF** taken into consideration (Spacer & Pad)

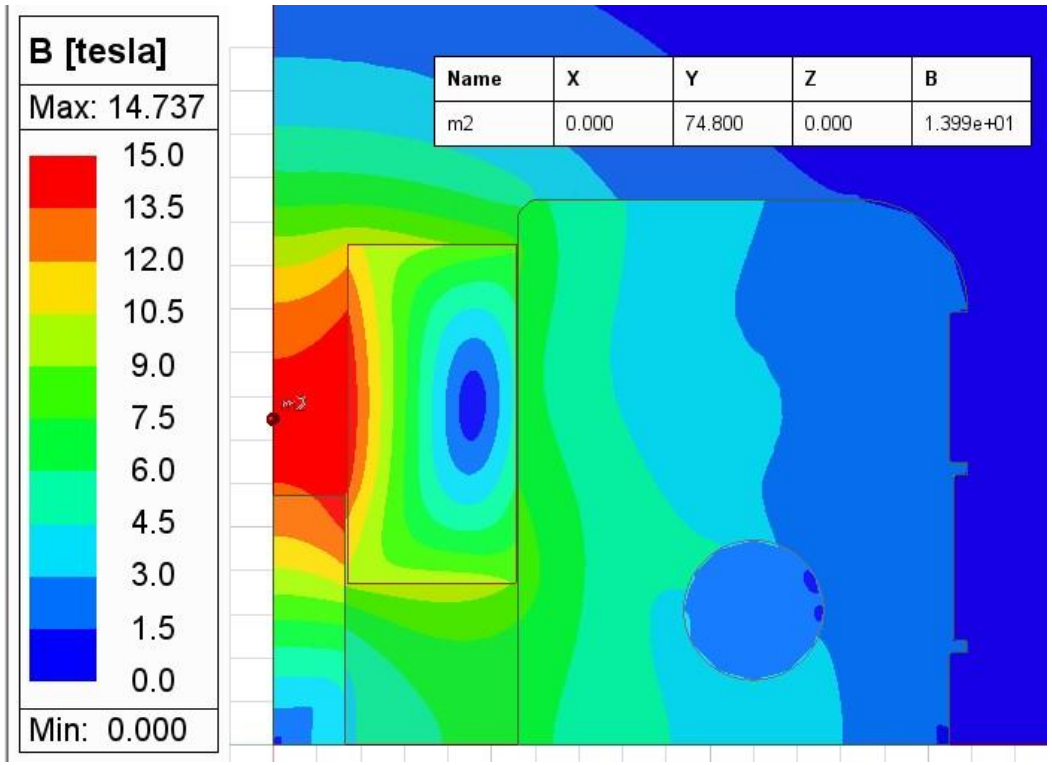


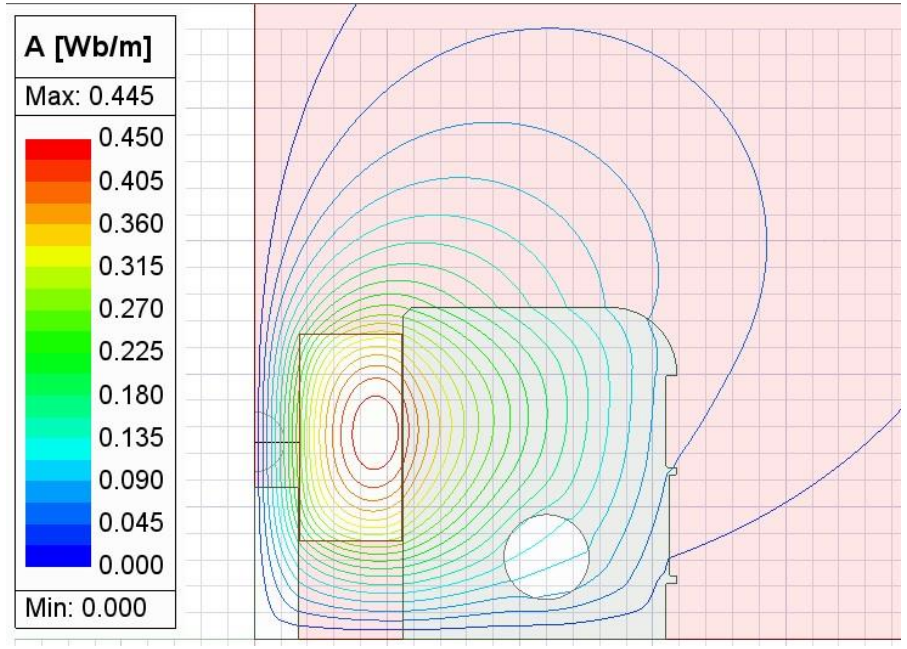


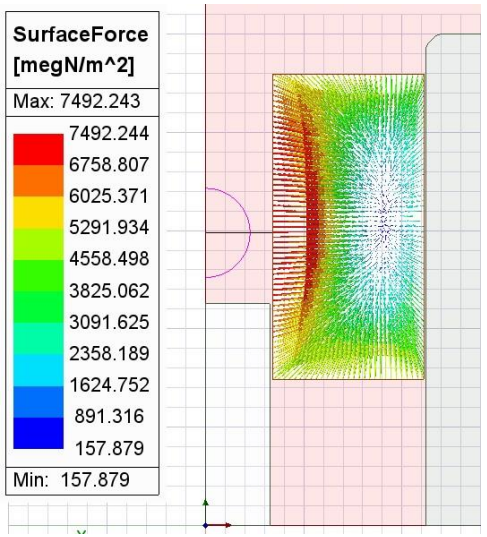
Maxwell 2D - 34mm aperture

- Intrabeam[(1)]: 149.6 mm
- Nominal Current: 19340 A
- Peak Field: 14.74 T
- **Aperture Field: 13.99 T**
- Middle Yoke height (Q1): 57.3 mm (0.5mm to aperture)

[(1)]: *a2* optimization



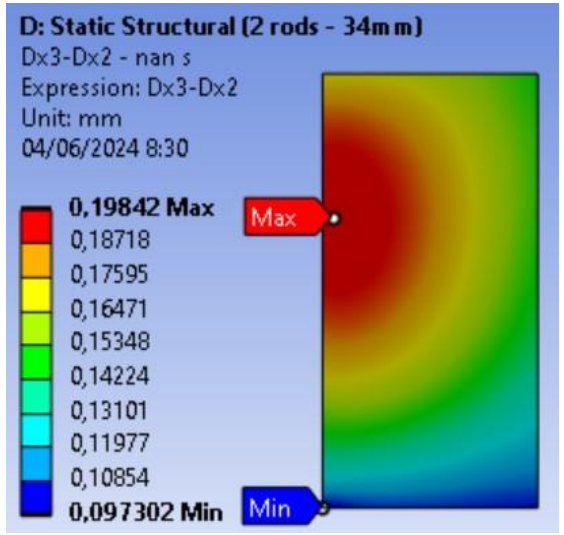




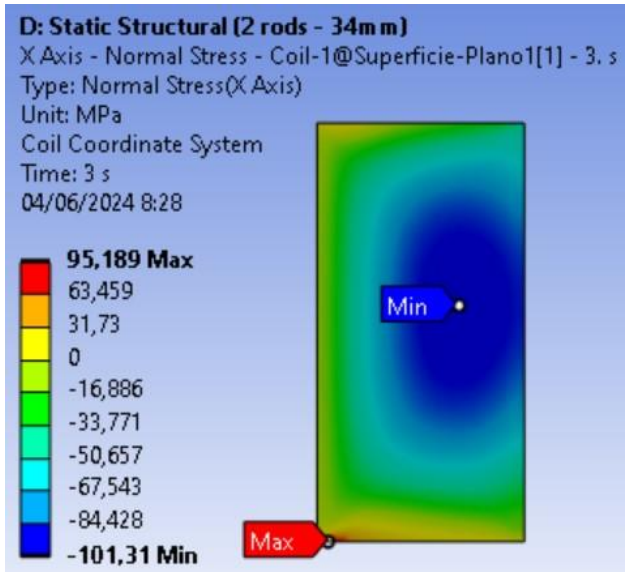
Fx (Coil)	6,397	MN/m
Fy (Coil)	0,441	MN/m
Total F (Coil)	6,412	MN/m
Fx (Spacer)	-0,916	MN/m
Fy (Spacer)	0,304	MN/m
Total F (Spacer)	0,965	MN/m
Fx (Pad)	-1,051	MN/m
Fy (Pad)	-0,253	MN/m
Total F (Pad)	1,081	MN/m

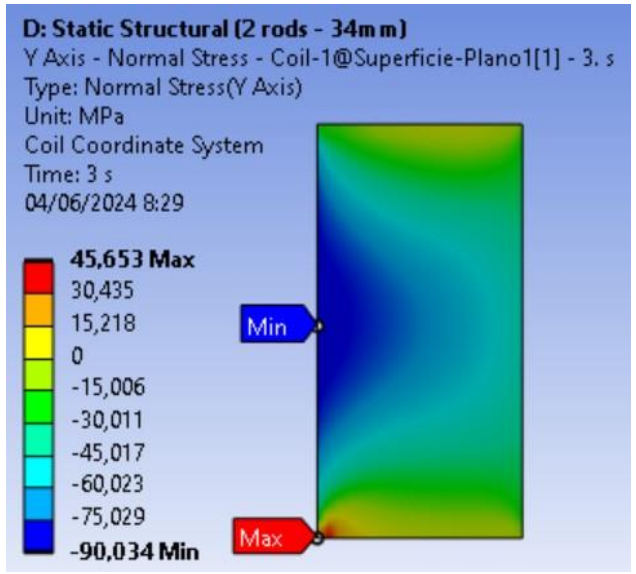
Ansys 2D - 34mm aperture

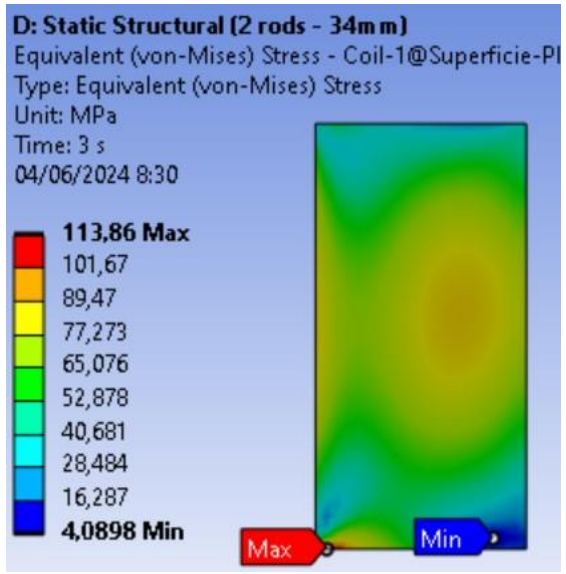
- Both keys in contact @ room temperature (20ºC). Cooling up to 1.9K
- Max. Horizontal Coil Displacement (X) due to EMF: **0.2** mm
- Max Stress @ Coil (Cooling + EMF):
  - Max X Stress @ Coil: 95.2 MPa (-101.3 MPa)
  - Max Y Stress @ Coil: 45.7 MPa (-90.0 MPa)
  - Max **VM** Stress @ Coil: **113.9** MPa
  - Max **Shear** Stress @ Coil: **47.8** MPa (located @ Pole – Coil transition)

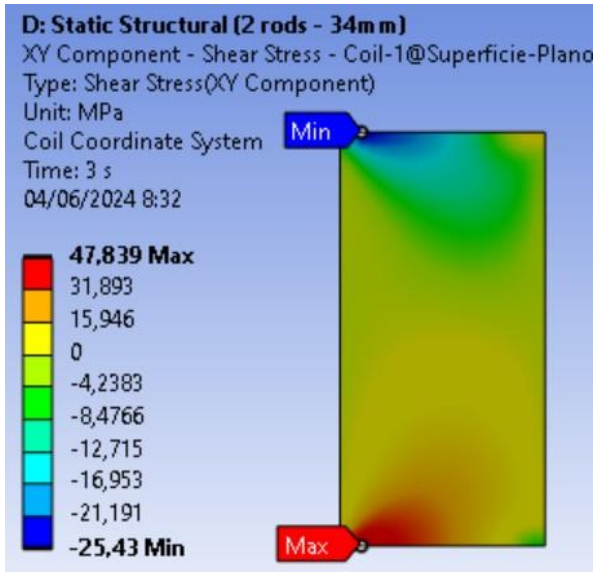


Coil Displacement due to EMF





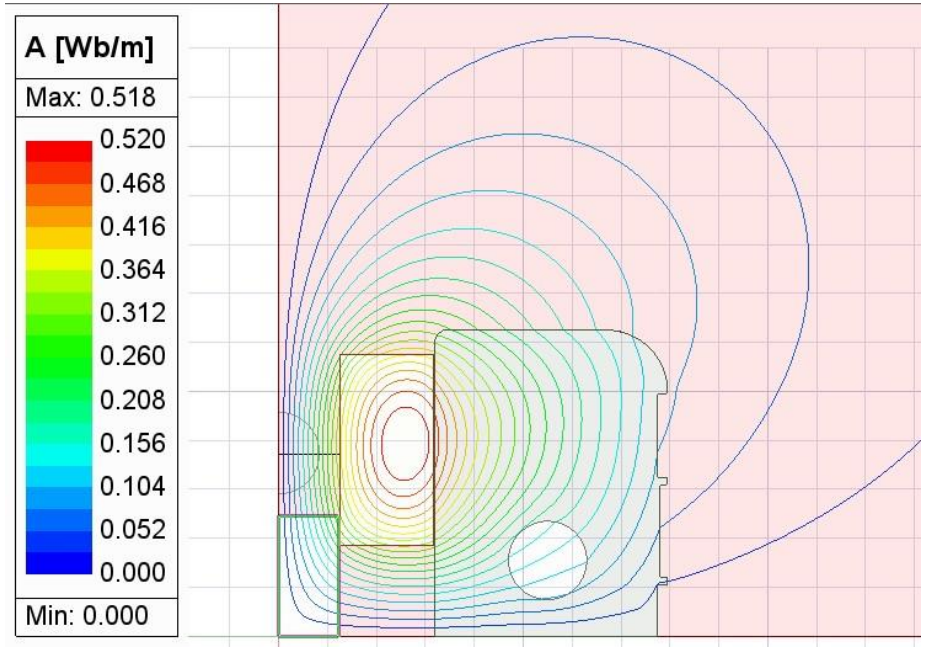


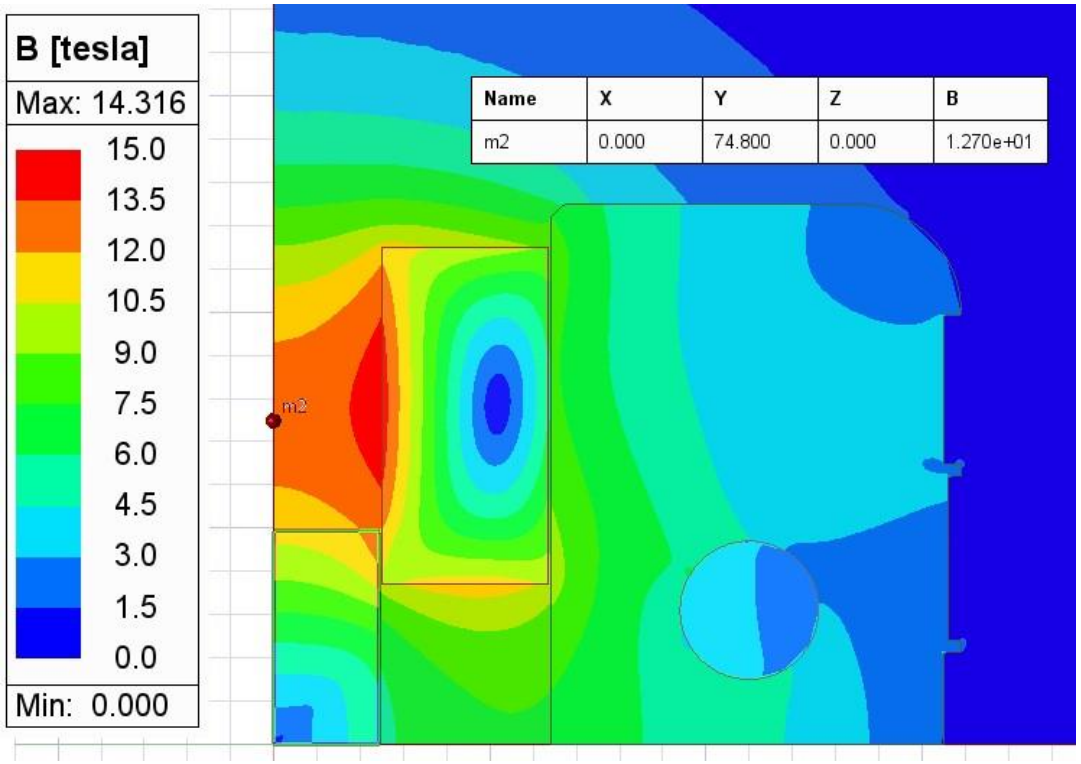


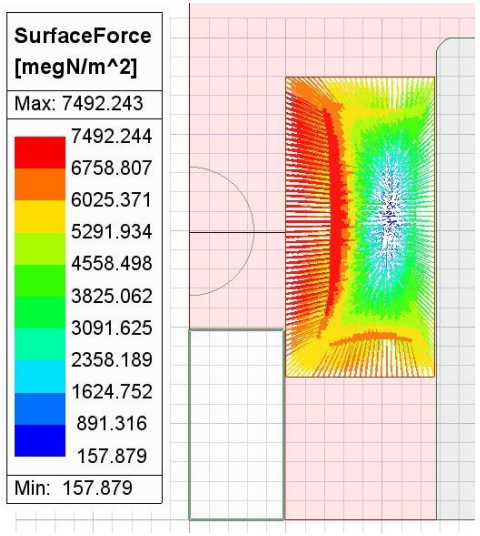
Maxwell 2D - 50mm aperture

- Intrabeam[(1)]: 149.6 mm
- Nominal Current: 20728 A
- Peak Field: 14.32 T
- **Aperture Field: 12.70 T**
- Middle Yoke height (Q1): 49.3 mm (0.5mm to aperture)

[(1)]: *a2* optimization



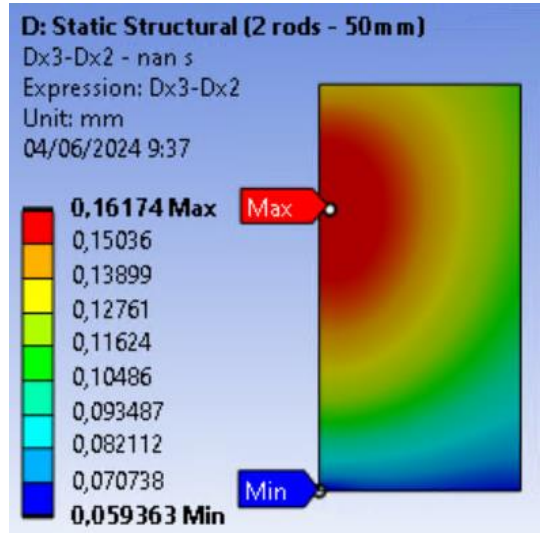




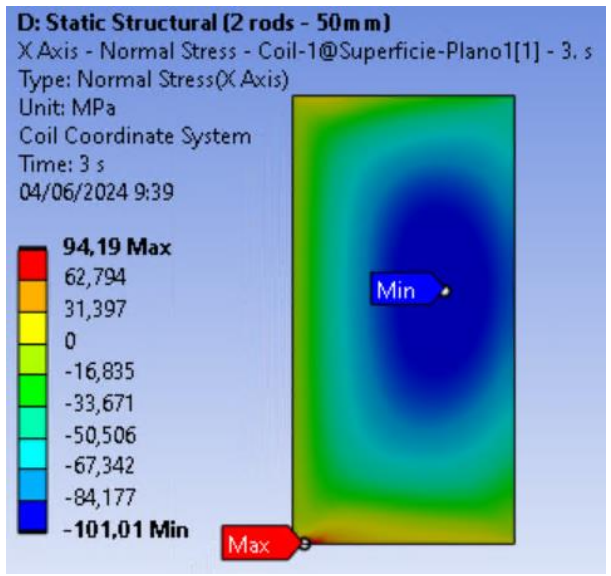
Fx (Coil)	5,830	MN/m
Fy (Coil)	0,830	MN/m
Total F (Coil)	5,889	MN/m
Fx (Spacer)	-0,327	MN/m
Fy (Spacer)	0,311	MN/m
Total F (Spacer)	0,452	MN/m
Fx (Pad)	-1,175	MN/m
Fy (Pad)	-0,403	MN/m
Total F (Pad)	1,242	MN/m

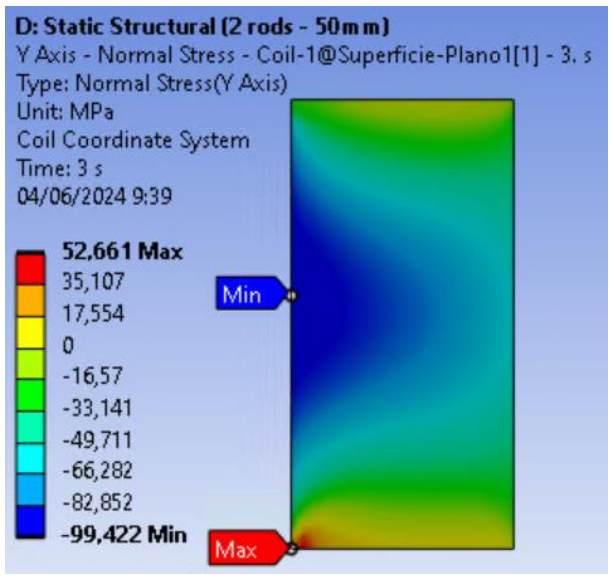
Ansys 2D - 50mm aperture

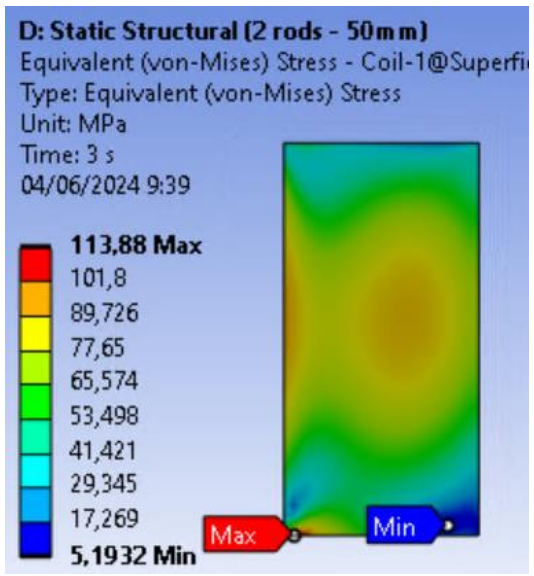
- Both keys in contact @ room temperature (20ºC). Cooling up to 1.9K
- Max. Horizontal Coil Displacement (X) due to EMF: **0.16** mm
- Max Stress @ Coil (Cooling + EMF):
  - Max X Stress @ Coil: 94.2 MPa (-101 MPa)
  - Max Y Stress @ Coil: 52.7 MPa (-99.4 MPa)
  - Max **VM** Stress @ Coil: **113.9** MPa
  - Max **Shear** Stress @ Coil: **48.4** MPa (located @ Pole – Coil transition)

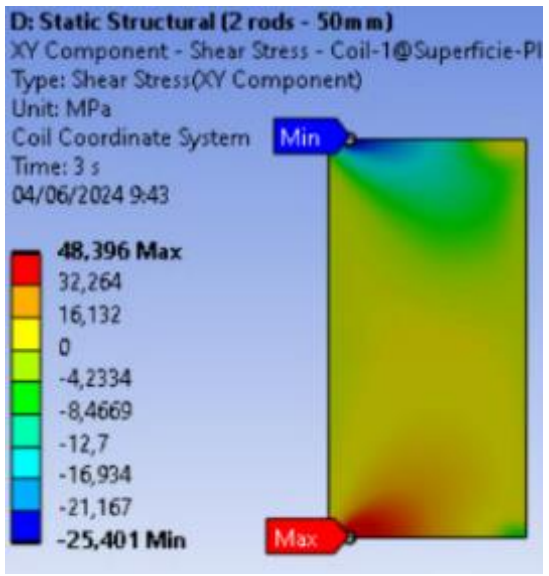


Coil Displacement due to EMF









Outline

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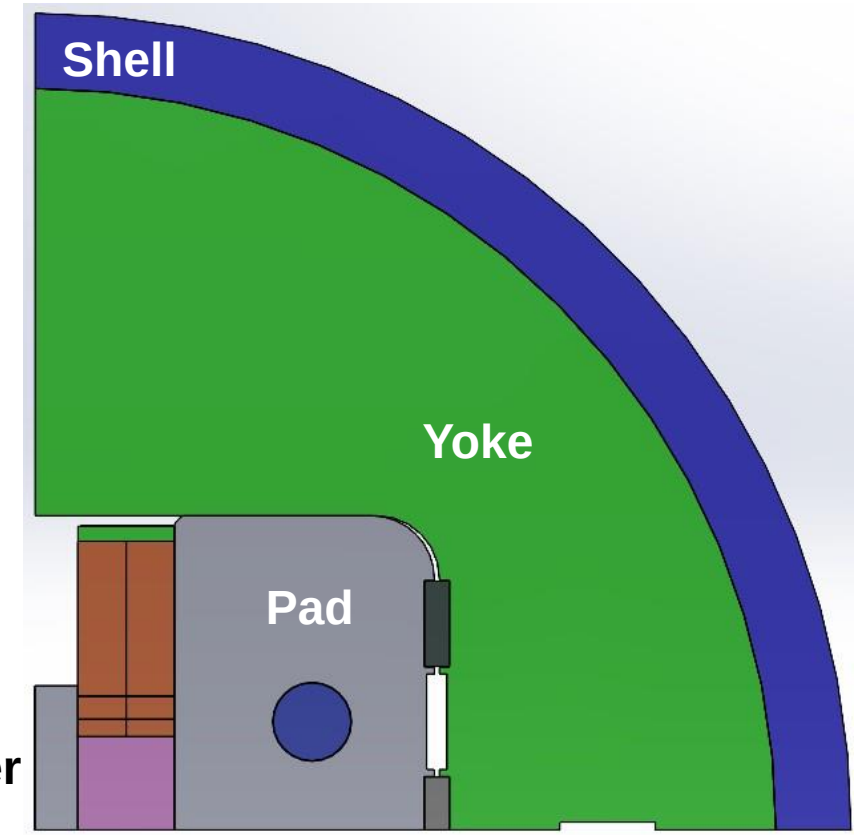
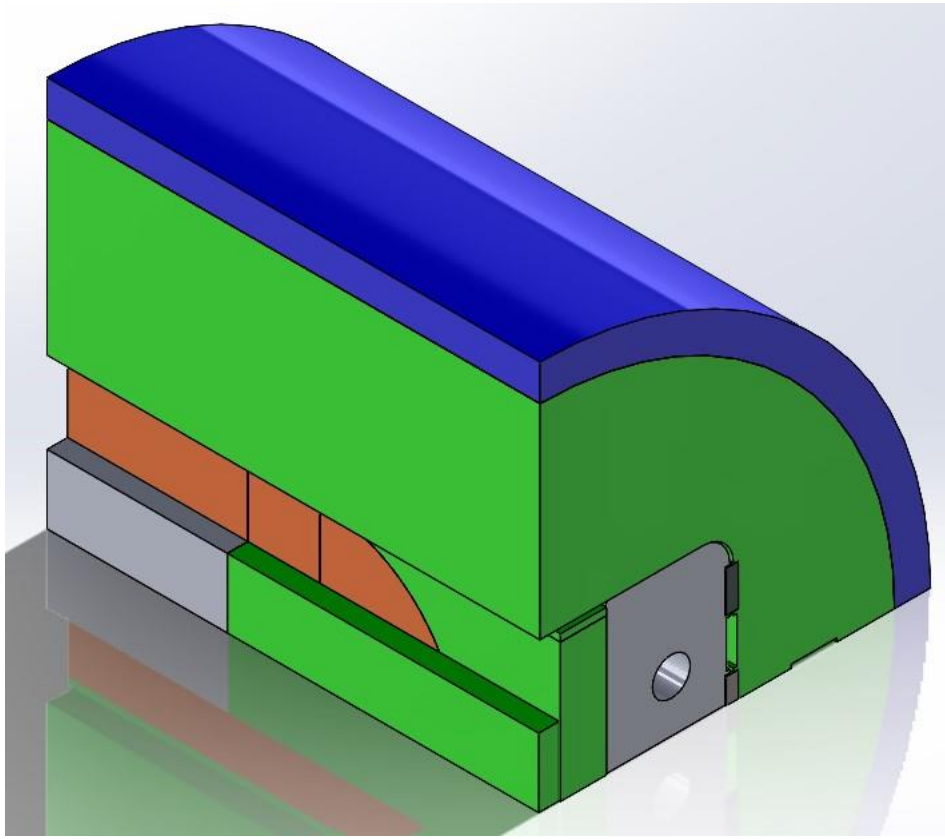
3D Design – 34mm aperture

- Geometry and thermal/magnetic conditions as in 2D design
- **No axial support**
- **Iron only in magnet straight section** (Spacer & Pad)



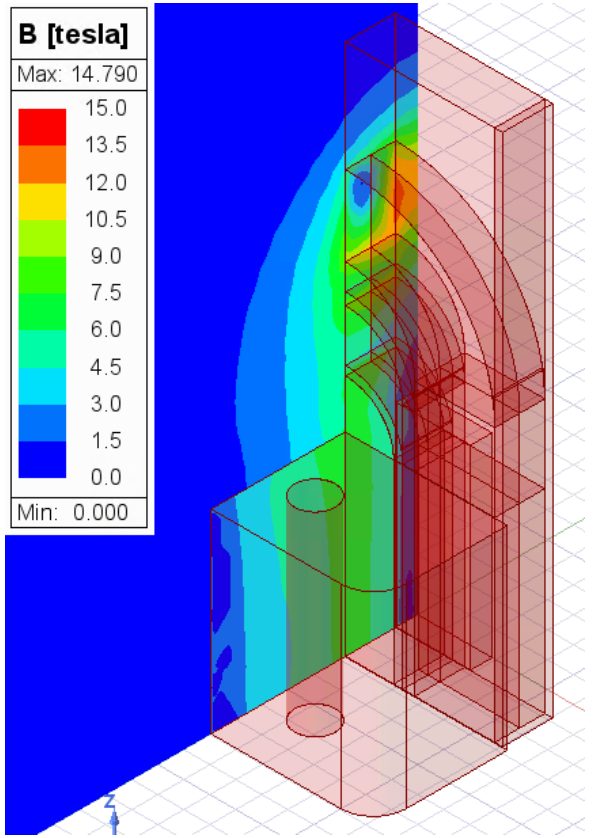


Maxwell 3D

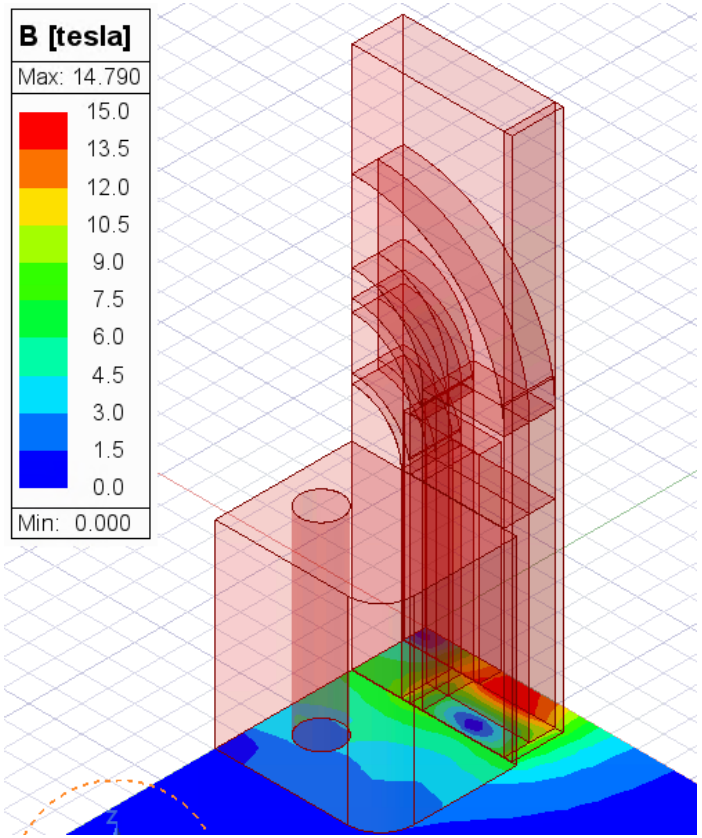
- Nominal current: 19340 A
- Aperture Field: **13.91 T**
- **Iron only** in magnet **straight section**

Fx (Coil)	1,692	MN	Fx (Spacer)	-198,160	kN	Fx (Pad)	-166,390	kN
Fy (Coil)	0,381	MN	Fy (Spacer)	-45,569	kN	Fy (Pad)	-52,368	kN
Fz (Coil)	0,249	MN	Fz (Spacer)	-22,374	kN	Fz (Pad)	-18,979	kN
Total F (Coil)	1,752	MN	Total F (Spacer)	204,560	kN	Total F (Pad)	175,460	kN

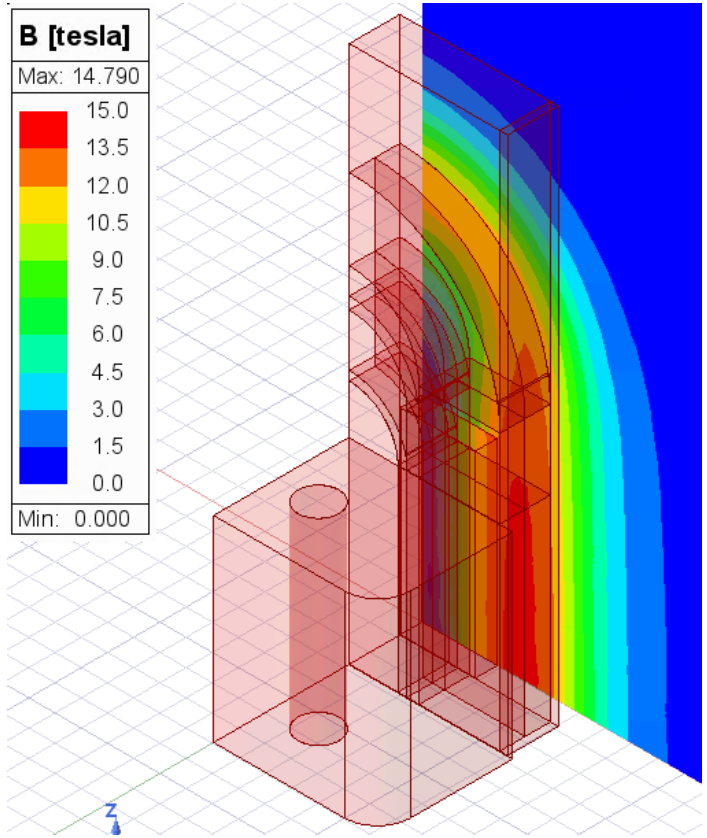
XZ



XY

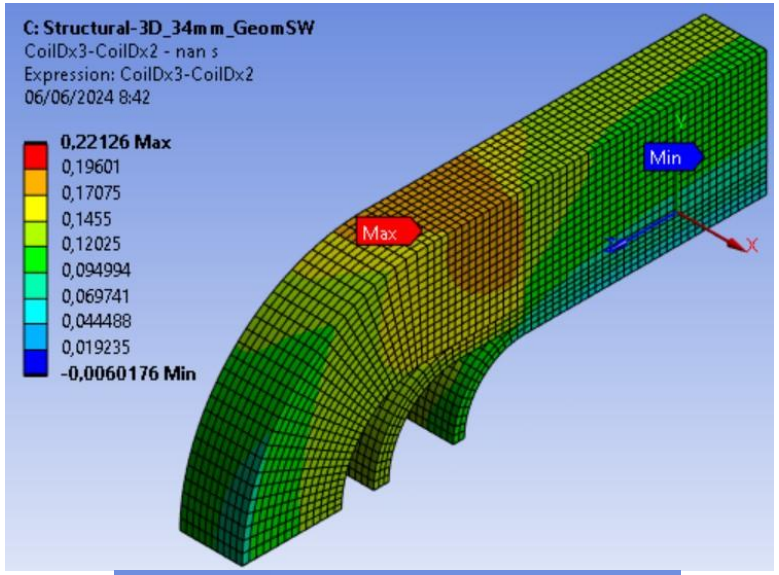


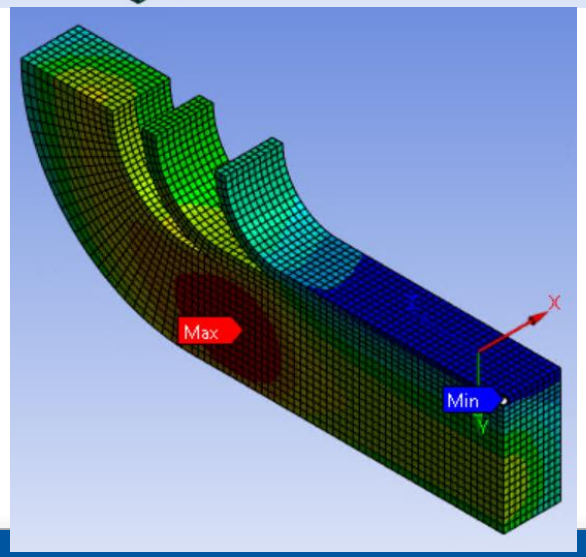
YZ



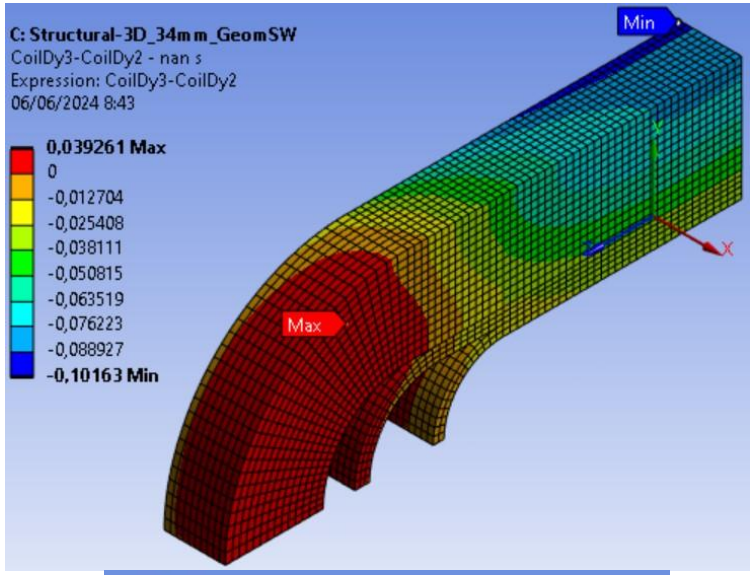
Ansys 3D: Coil Displacement due to EMF

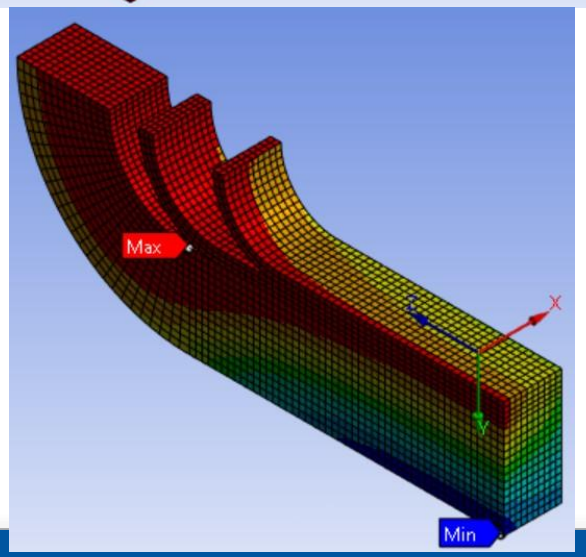
X direction: **+0.22** mm



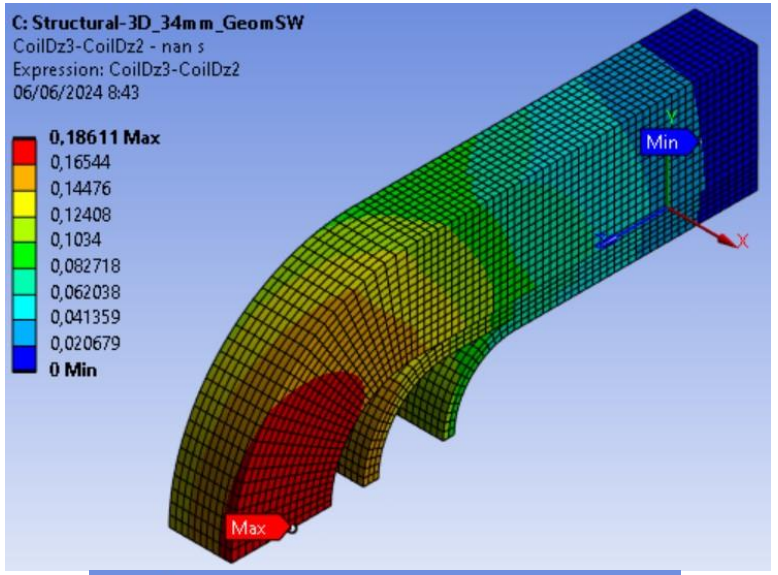


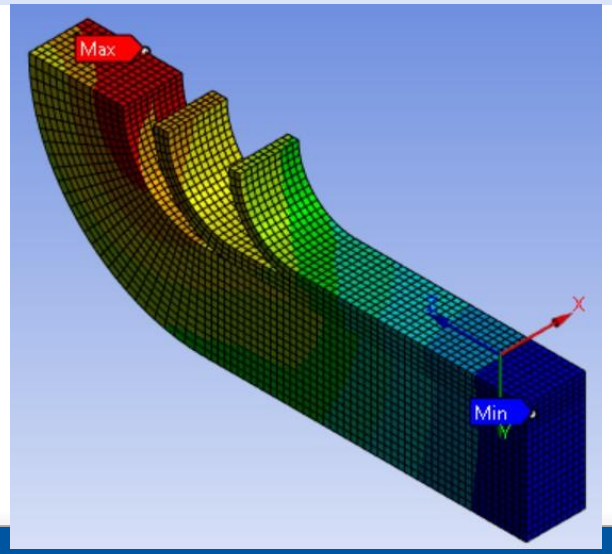
Y direction: **-0.10** mm





Z direction: +**0.19** mm

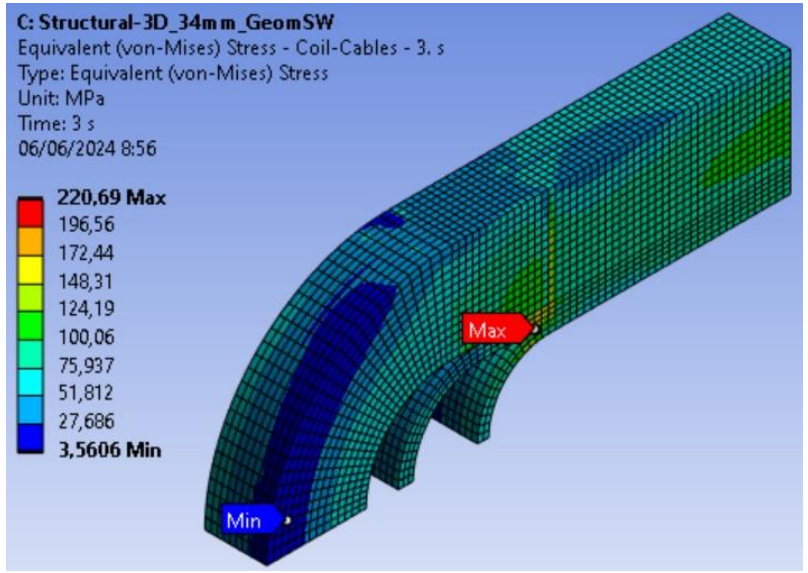




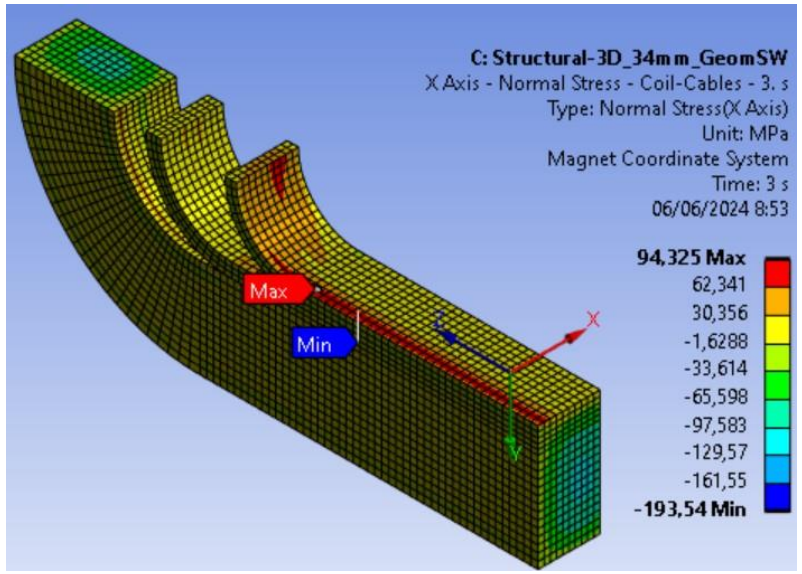
Ansys 3D: Coil stress

	COIL			
	X stress	Y stress	Z stress	VM stress
Max	94,325 MPa	117,41 MPa	**222,56 MPa**	**220,69 MPa**
Min	-193,5 MPa	-78,57 MPa	-51,59 MPa	3,5606 MPa

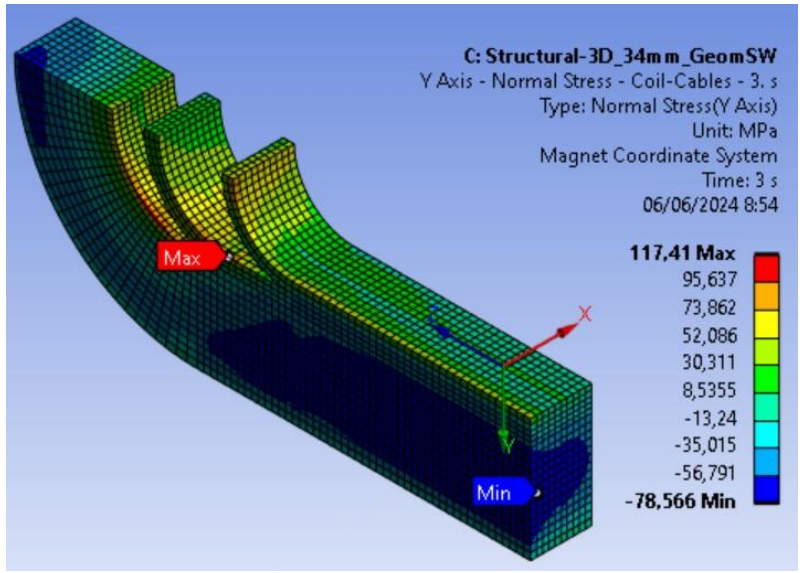
Eq. VM



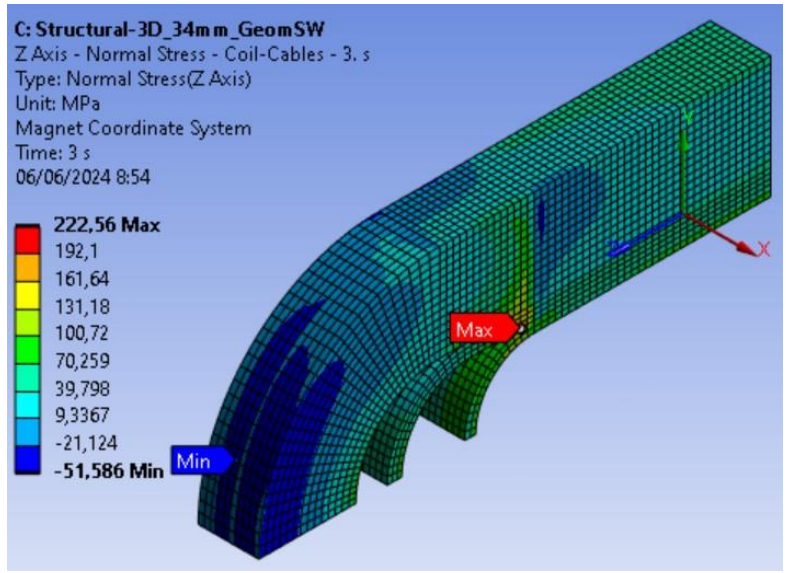
X



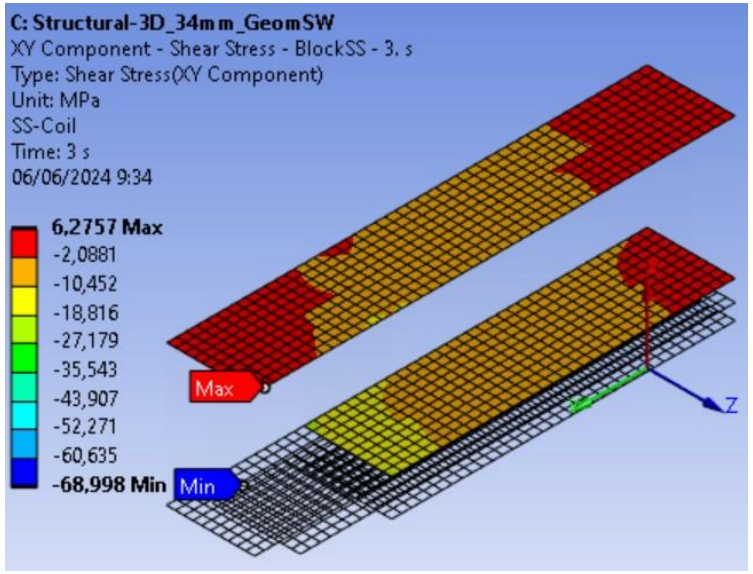
Y

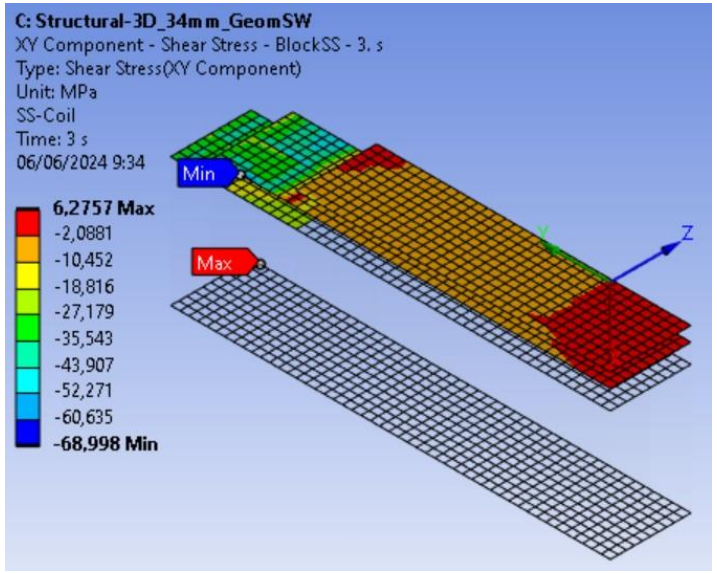


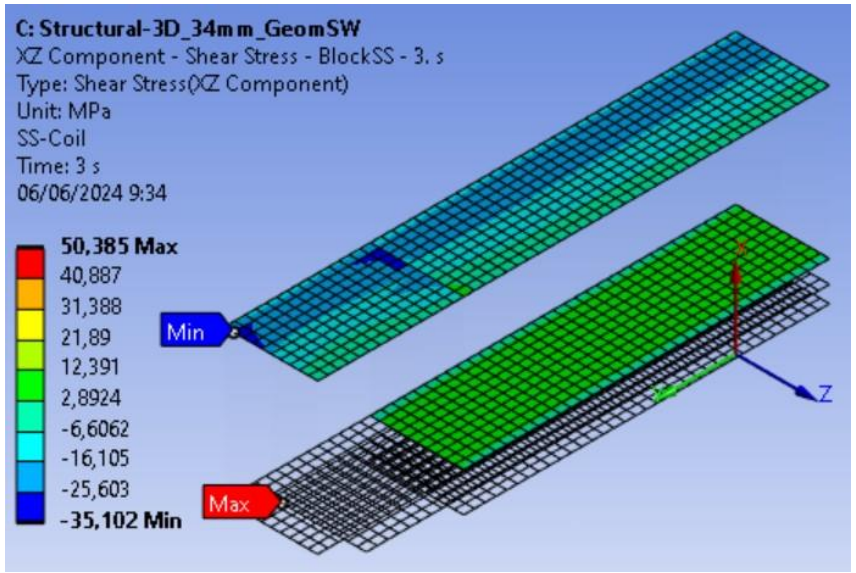
Z

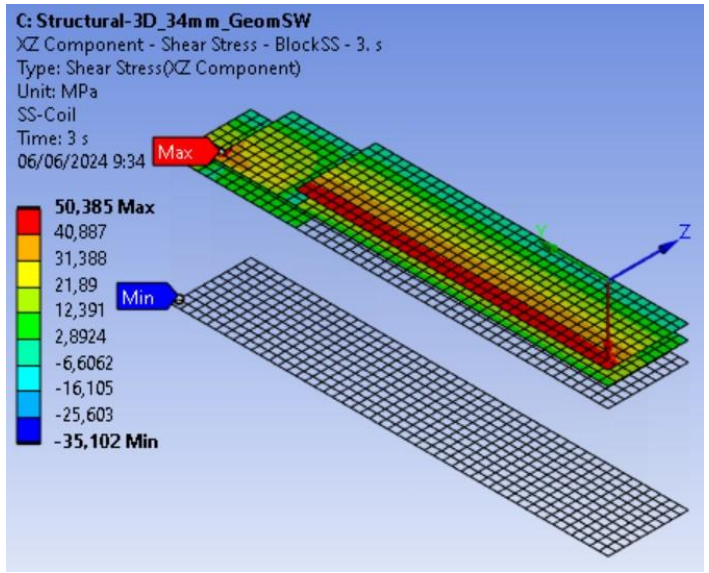


Ansys 3D: Coil planar surfaces Shear stress





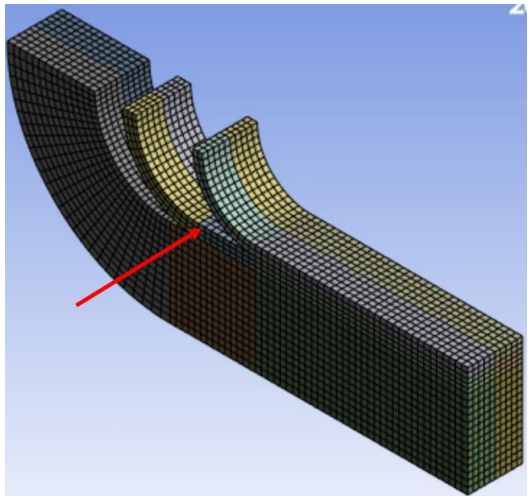




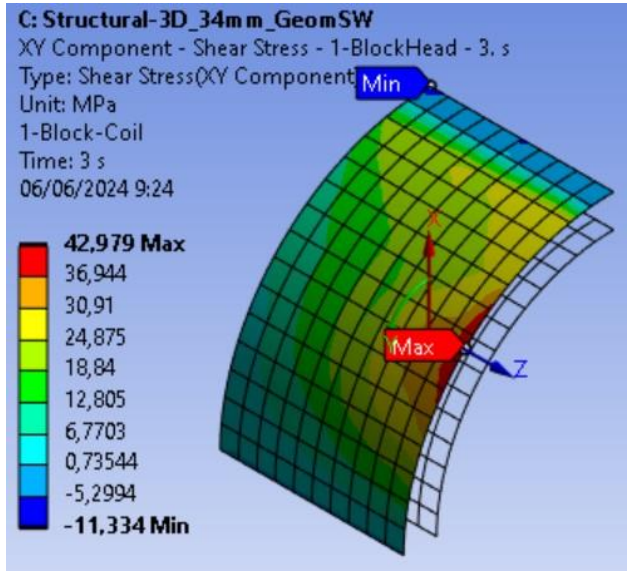
	COIL (Planar surfaces)	
	XY Sh. stress	XZ Sh. stress
Max	6,2757 MPa	**50,385 MPa**
Min	**-69 MPa**	-35,1 MPa

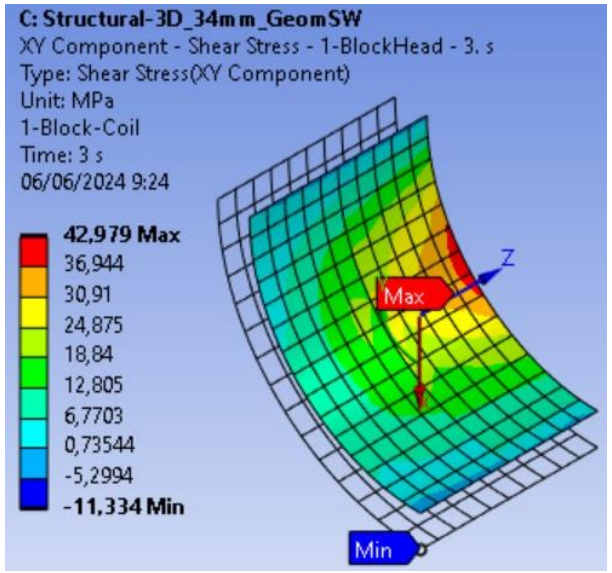
Max Shear Stress: Second cable Block contact with Coil Spacer

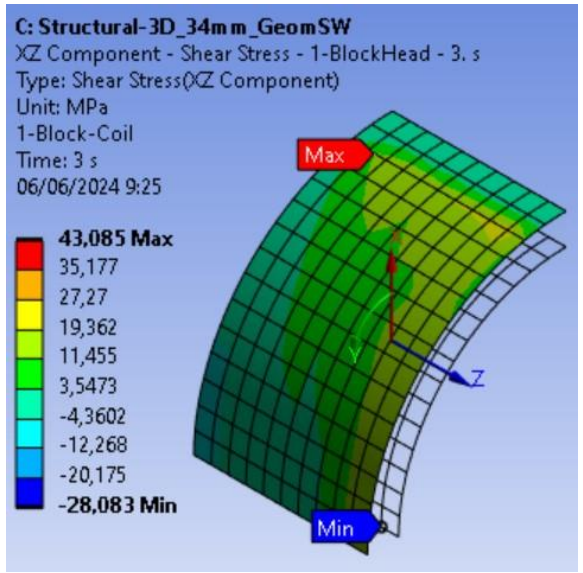
(Magnet Spacer side)

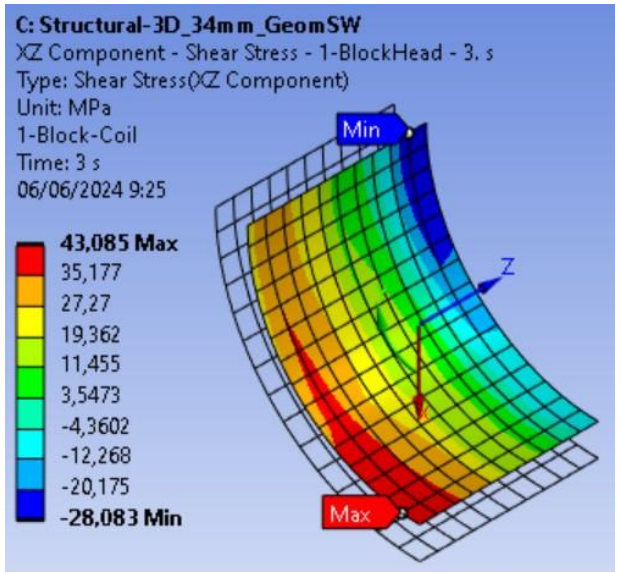


Ansys 3D: Coil 1st Block Head surfaces Shear stress





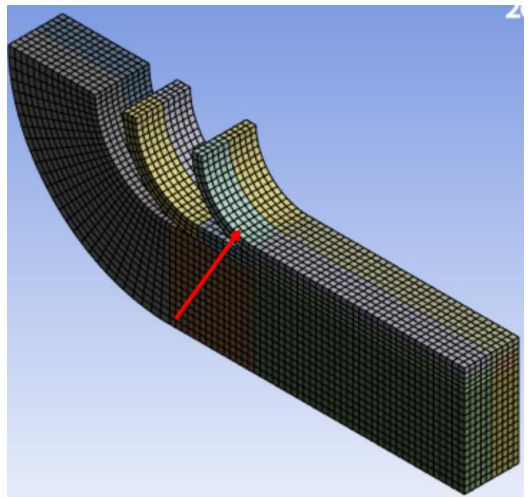




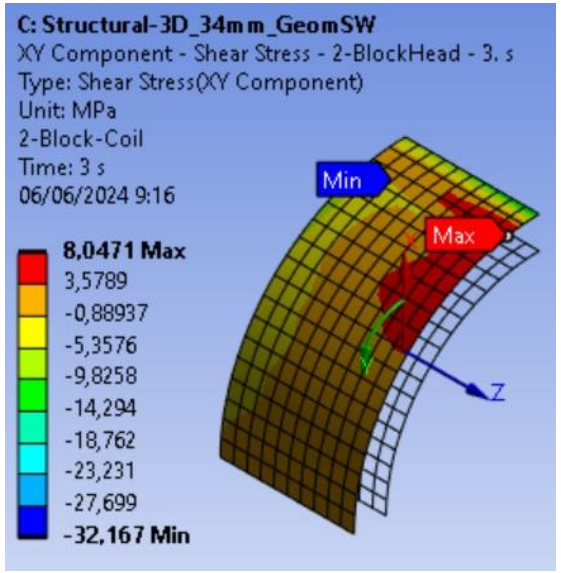
	COIL (1st Block surfaces)	
	XY Sh. stress	XZ Sh. stress
Max	42,979 MPa	43,085 MPa
Min	-11,33 MPa	-28,08 MPa

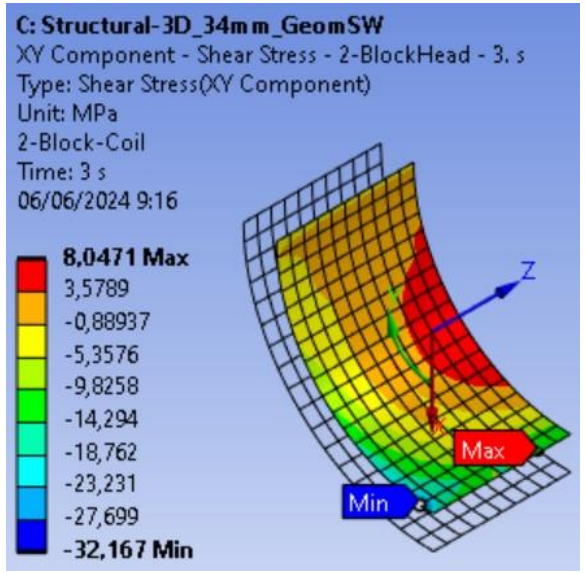
Max Shear Stress: First cable Block contact with Pole

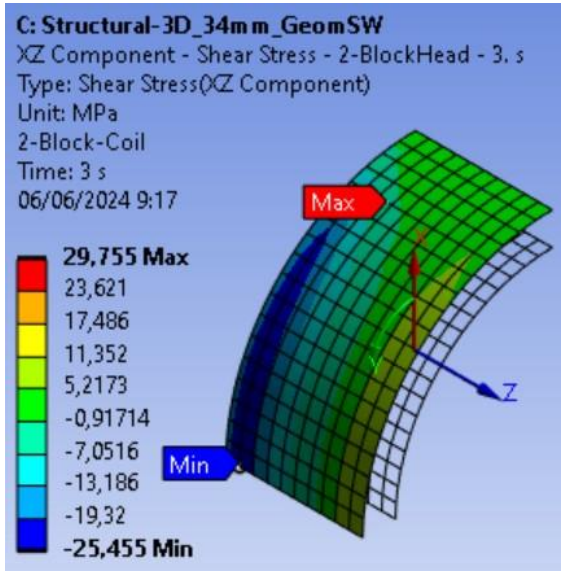
(Magnet Spacer side)

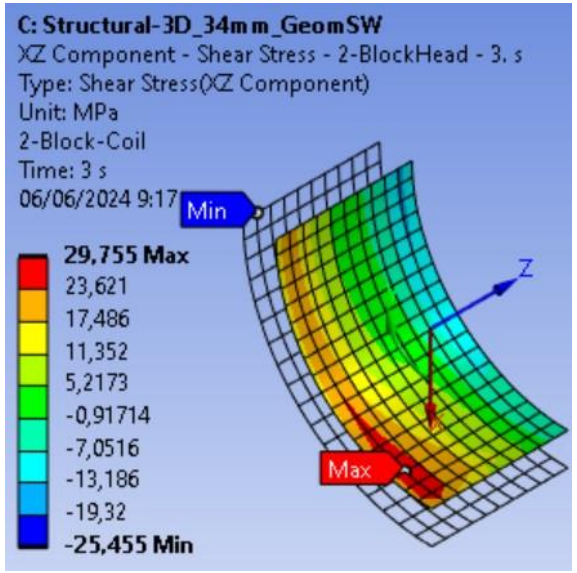


Ansys 3D: Coil 2nd Block Head surfaces Shear stress





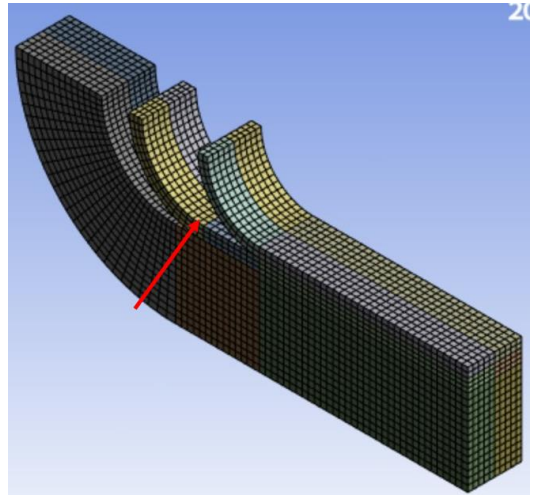




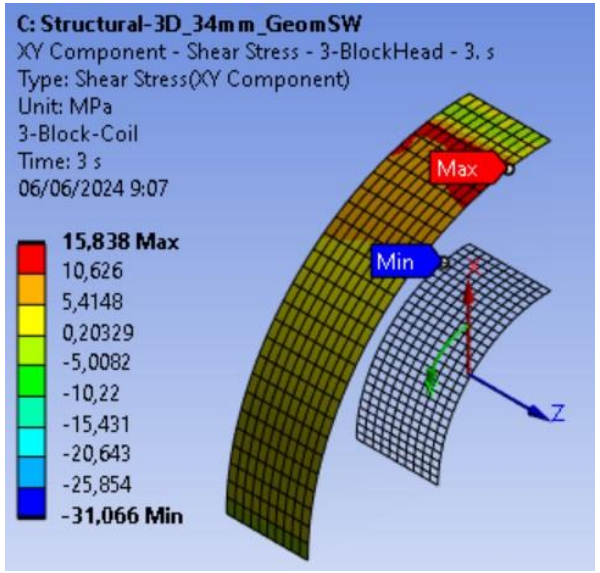
	COIL (2nd Block surfaces)	
	XY Sh. stress	XZ Sh. stress
Max	8,0471 MPa	29,755 MPa
Min	-32,167 MPa	-25,46 MPa

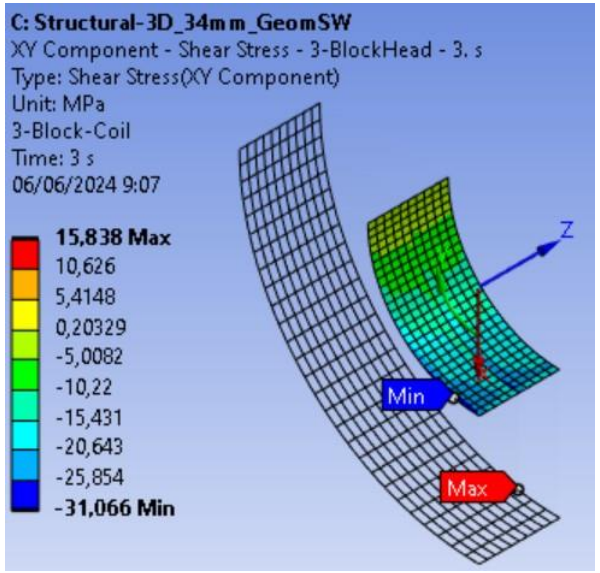
Max Shear Stress: Second cable Block contact with Coil Spacer

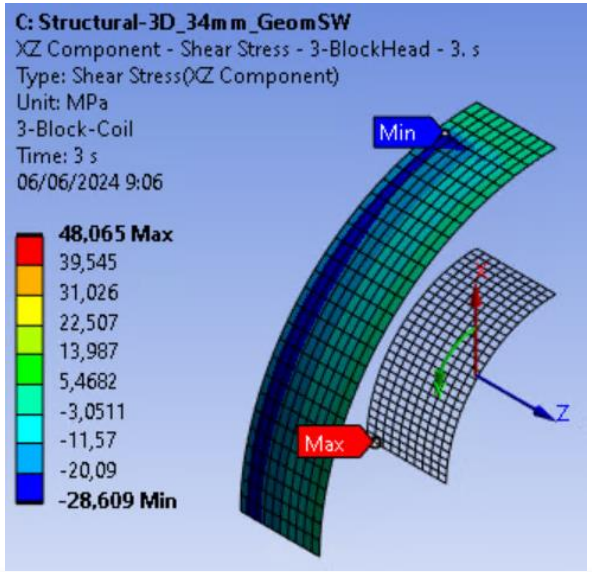
(Magnet Spacer side)

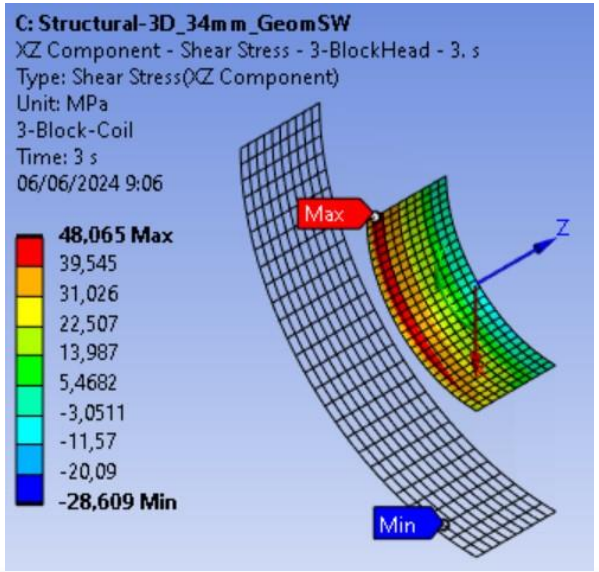


Ansys 3D: Coil 3rd Block Head surfaces Shear stress





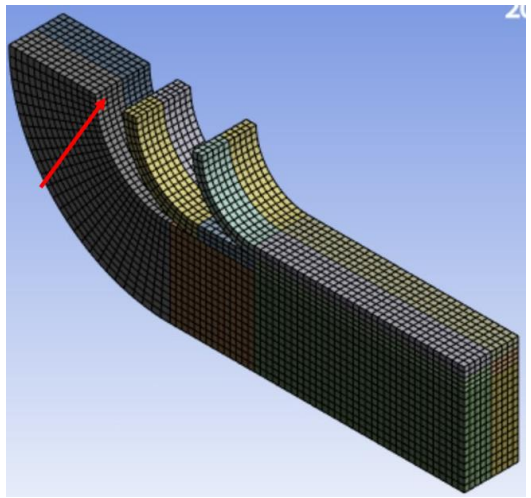




	COIL (3rd Block surfaces)	
	XY Sh. stress	XZ Sh. stress
Max	15,839 MPa	48,065 MPa
Min	-31,07 MPa	-28,61 MPa

Max Shear Stress: Third cable Block contact with Coil Spacer

(Magnet Spacer side)



Outline

- ISAAC goals & constraints (reminder)
- 2D Design update
  - 34 mm aperture
  - 50 mm aperture
- 3D Design (34mm aperture)
  - Magnetic – Maxwell
  - Mechanical – Ansys
- Conclusions

Conclusions (2D design)

- ISAAC 2D design updated for 34mm and 50mm aperture:
  - Shell outer diameter up to 650mm
  - EMF over iron Spacer & iron Pad
- Max. Horizontal Coil Displacement (X) due to EMF: 0.2 mm
- Concerns about “unavoidable” shear stress in coil contact with the pole (about 50 MPa for 34mm aperture)
- Max. VM Coil stress about 115 MPa for 34mm aperture (below 150 MPa)

- Influence of Iron Spacer small displacements on ISAAC performance

Conclusions (3D design)

- First 3D simulations with iron only in magnet straight section & no axial support
  - Max. horizontal coil displacement due to EMF: 0.22mm
  - Max. axial coil displacement due to EMF: 0.19mm
  - Max. VM Coil stress about 221 MPa
  - Max. Shear Coil stress about 69 MPa
- 3D design analysis ongoing:
  - Iron all magnet length (Spacer & Pad)
  - Iron Pad all magnet length & Spacer only in magnet straight section
  - Axial preload
  - Magnet assembly strategy (preload sequence)