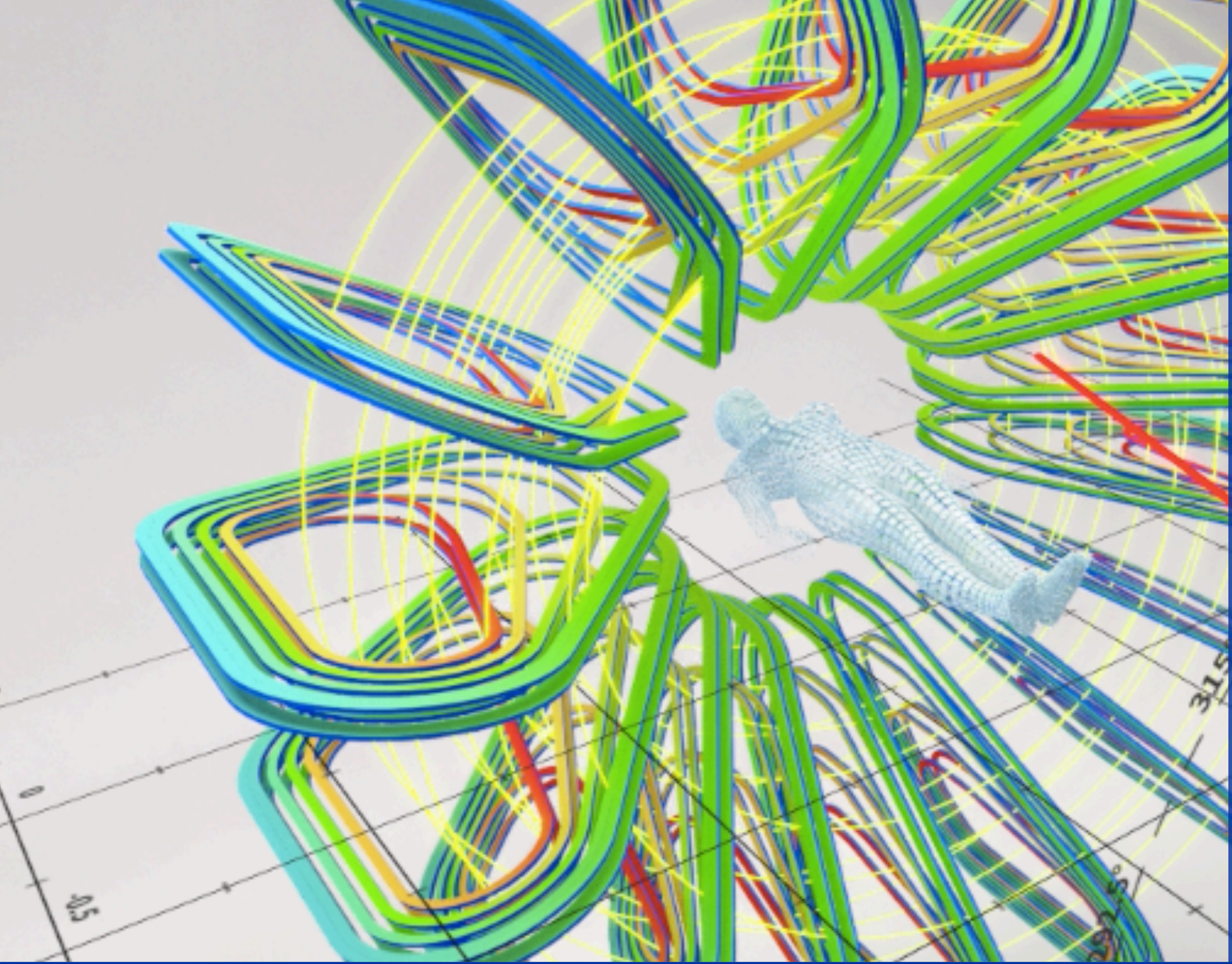
HTS Demonstrator Mechanics

GaToroid Project

Jérôme Harray

February 7, 2020



GaToroid Project

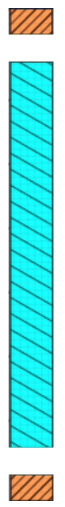
- Demonstration of HTS technology
- Development of a prototype in scalable conditions
- Coil box design to freeze magnet nominal position
- Bolt stress state assessment

Contact modeling

	Gap open/ close?	Sliding allowed?
Bonded	No	No
Frictionless	Yes	Yes, $\mu = 0$
Frictional	Yes	Yes, $F_{sliding} > F_{friction}$

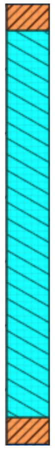
Pole - contact

- Contact between the **pole** & 1^{th} **tape stack** → **frictionless**
- Pre-constraint check-point → **pressure inspection**
- Pole material → pre-constraint strategy with $\alpha_{pole} < \alpha_{rim}$



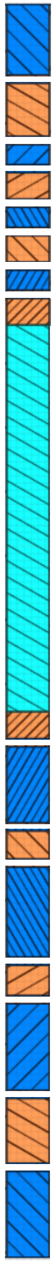
Pole - contact

- Contact between the **pole** & 1^{th} **tape stack** → **frictionless**
- Pre-constraint check-point → **pressure inspection**
- Pole material → pre-constraint strategy with $\alpha_{pole} < \alpha_{rim}$



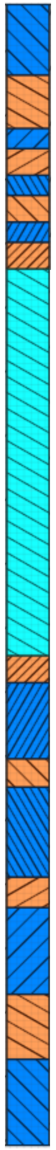
Windings - contact

- If resin assumed as **non-structural** → **frictional** contact $\mu = 0.3$
- If resin keeps components altogether → **bonded** contact
- **Contact stress magnitude** to keep the contact between components
- Warnings: **linear** model → **dynamic** effects & **crack** propagation dismissed



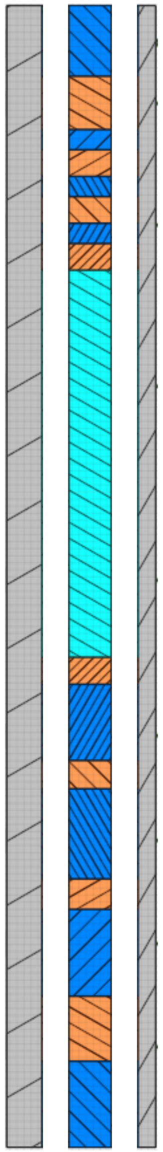
Windings - contact

- If resin assumed as **non-structural** $\rightarrow$ **frictional** contact $\mu = 0.3$
- If resin keeps components altogether $\rightarrow$ **bonded** contact
- **Contact stress magnitude** to keep the contact between components
- Warnings: **linear** model $\rightarrow$ **dynamic** effects & **crack** propagation dismissed



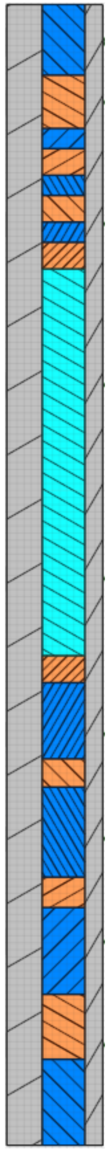
Coil box - contact

- Contact mainly subjected to **shear** from **contraction** & **Lorentz forces**
- Assumed all-time as **frictional** with $\mu = 0.3$



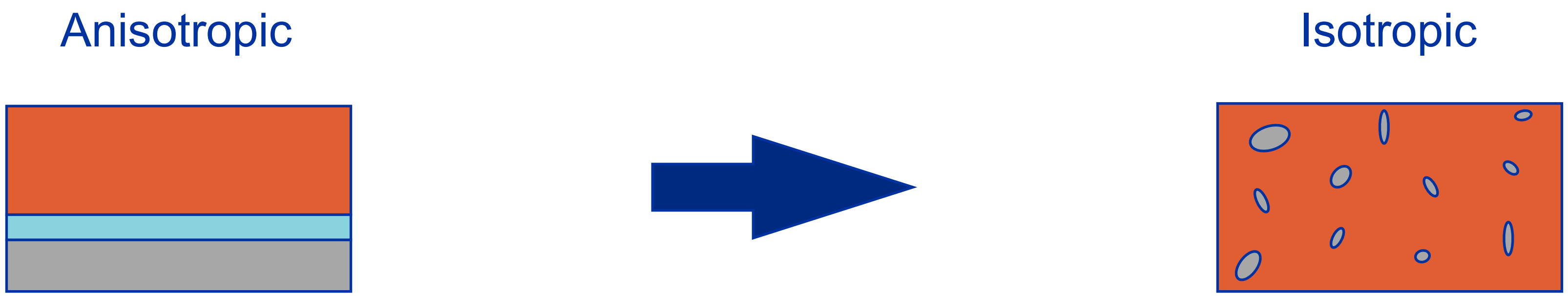
Coil box - contact

- Contact mainly subjected to **shear** from **contraction** & **Lorentz forces**
- Assumed all-time as **frictional** with $\mu = 0.3$



Isotropic tape model

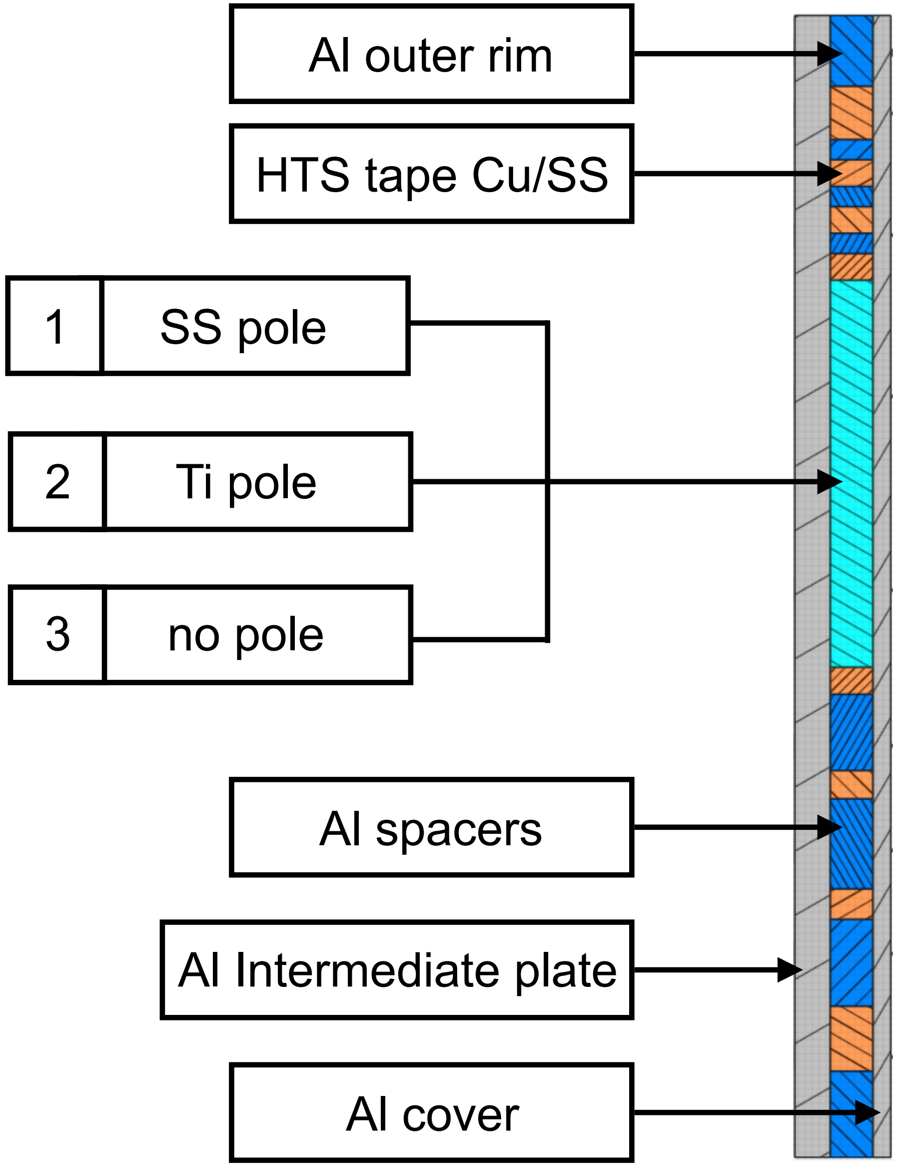
- Tape material composition: 70% SS & 30% Cu
- HTS cable with **insulation** composition: 19% SS & 81% Cu
- **Stacked** layout → **anisotropic** ~ orthotropic
- Lack of data → material model **simplification**



Material configurations

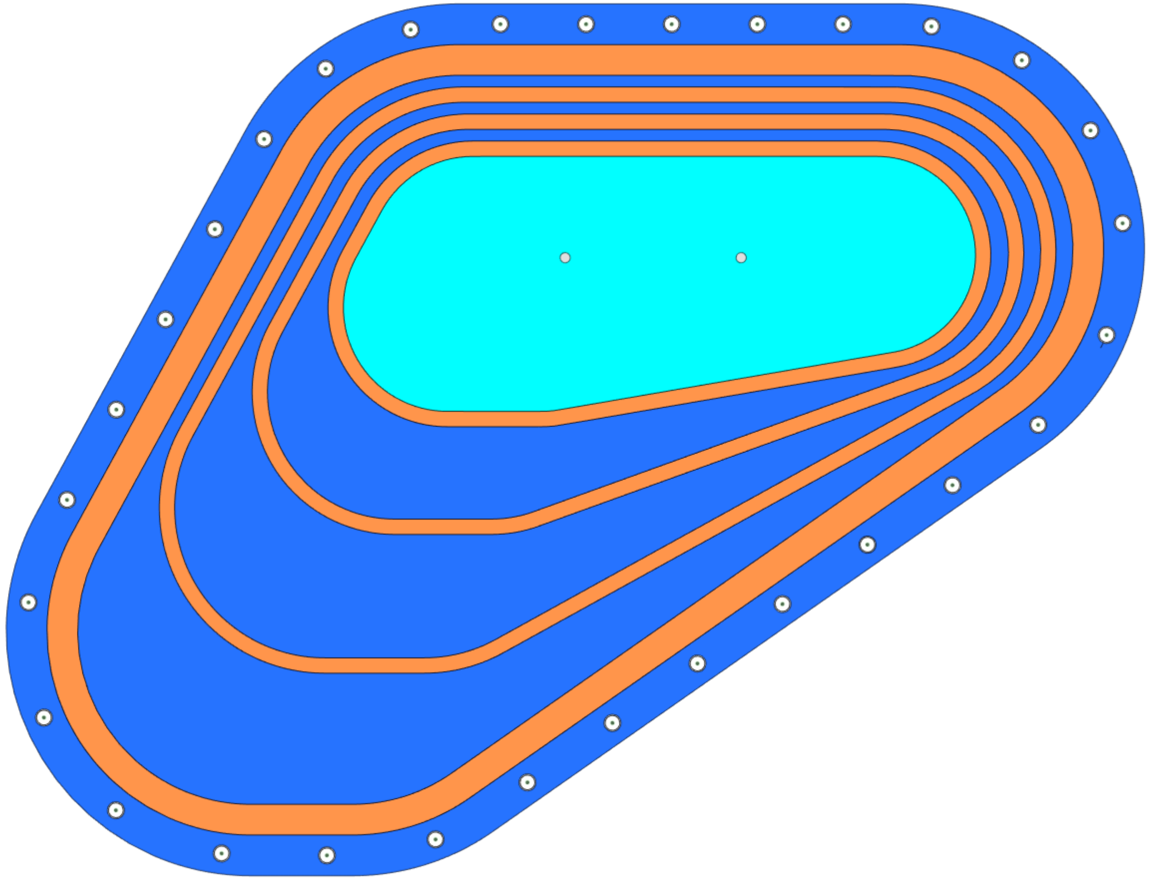
- Use of **Aluminium** for **structural** components
- Different **pre-constraint** strategies:
  1. Stainless Steel pole
  2. Titanium pole
  3. No pole

	Al	SS	Ti	HTS mixture
α [C^{-1}]	1,44E-05	9,9E-06	5E-06	1,10E-05



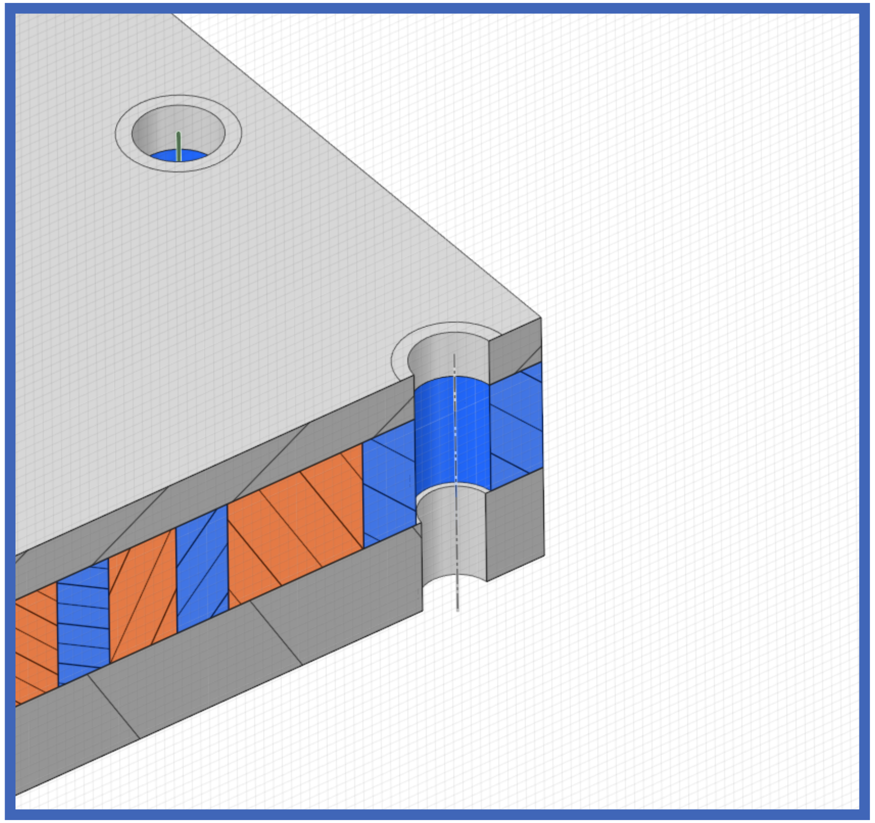
Bolts - layout

- **30 x M8 bolts** equally spaced along outer rim
- Pole falsely fixed at its centre
- Spacers **unpinned** in nominal conditions
- **Fixed spacers** configuration inspected

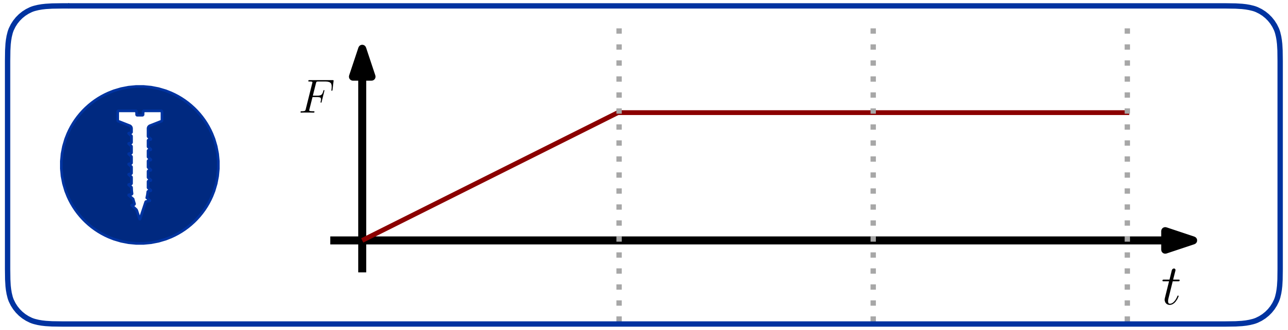


Bolts - modeling

- Load transmission
  - **Thread** in intermediate plate
  - **Head** surface on cover plate
- Bolt body simplified as **body line**
- **Pretension** applied on body line

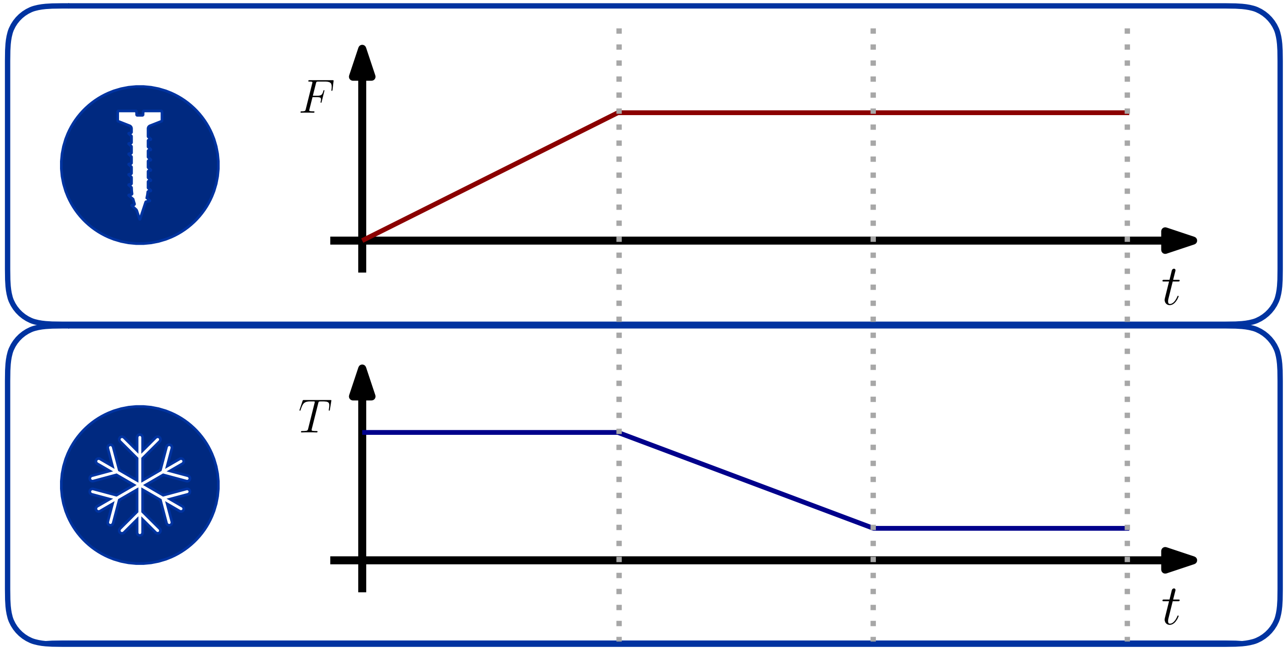


Multi-step static analysis



(1) Bolt pretension

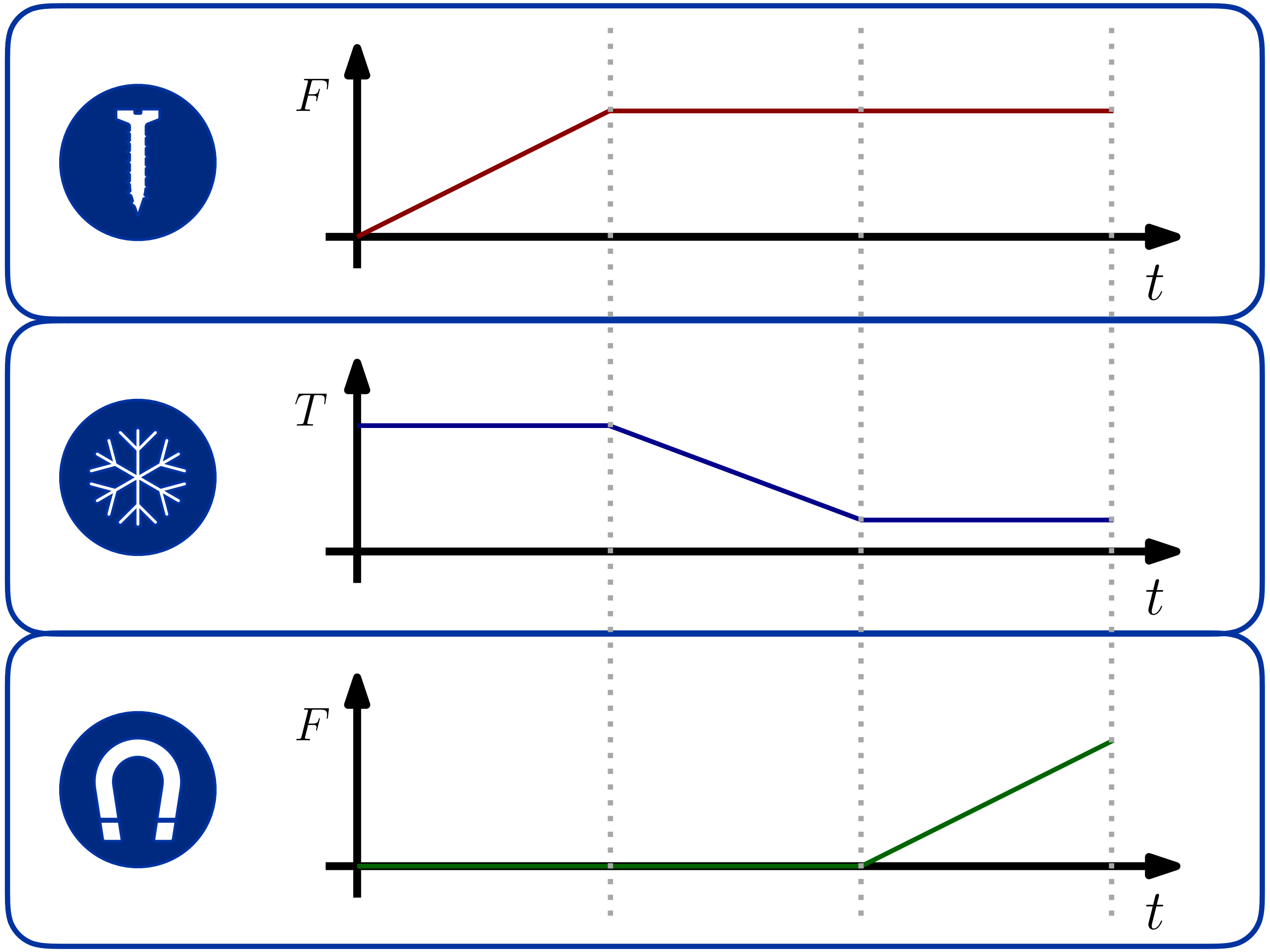
Multi-step static analysis



(1) Bolt pretension

(2) Cool-down

Multi-step static analysis



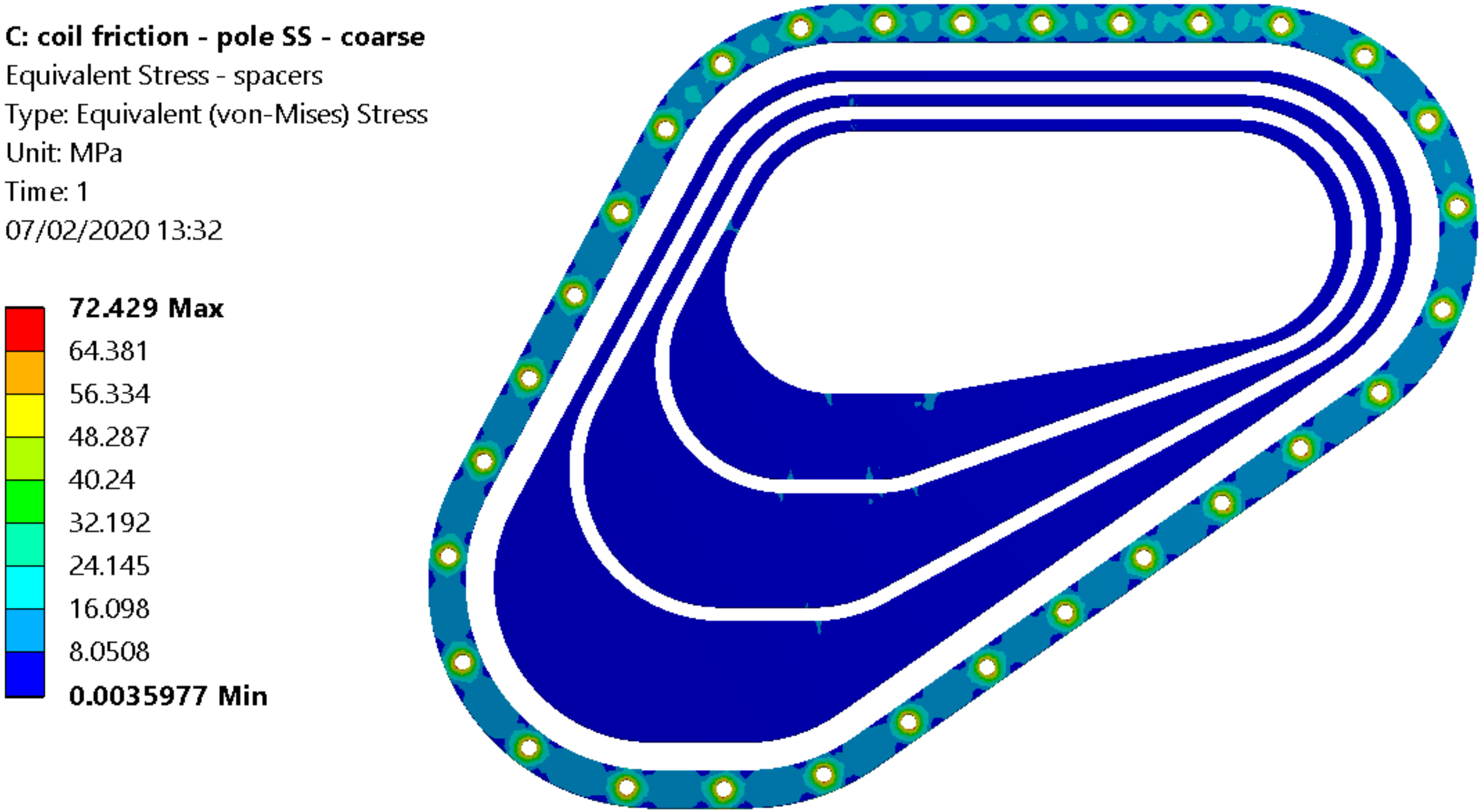
(1) Bolt pretension

(2) Cool-down

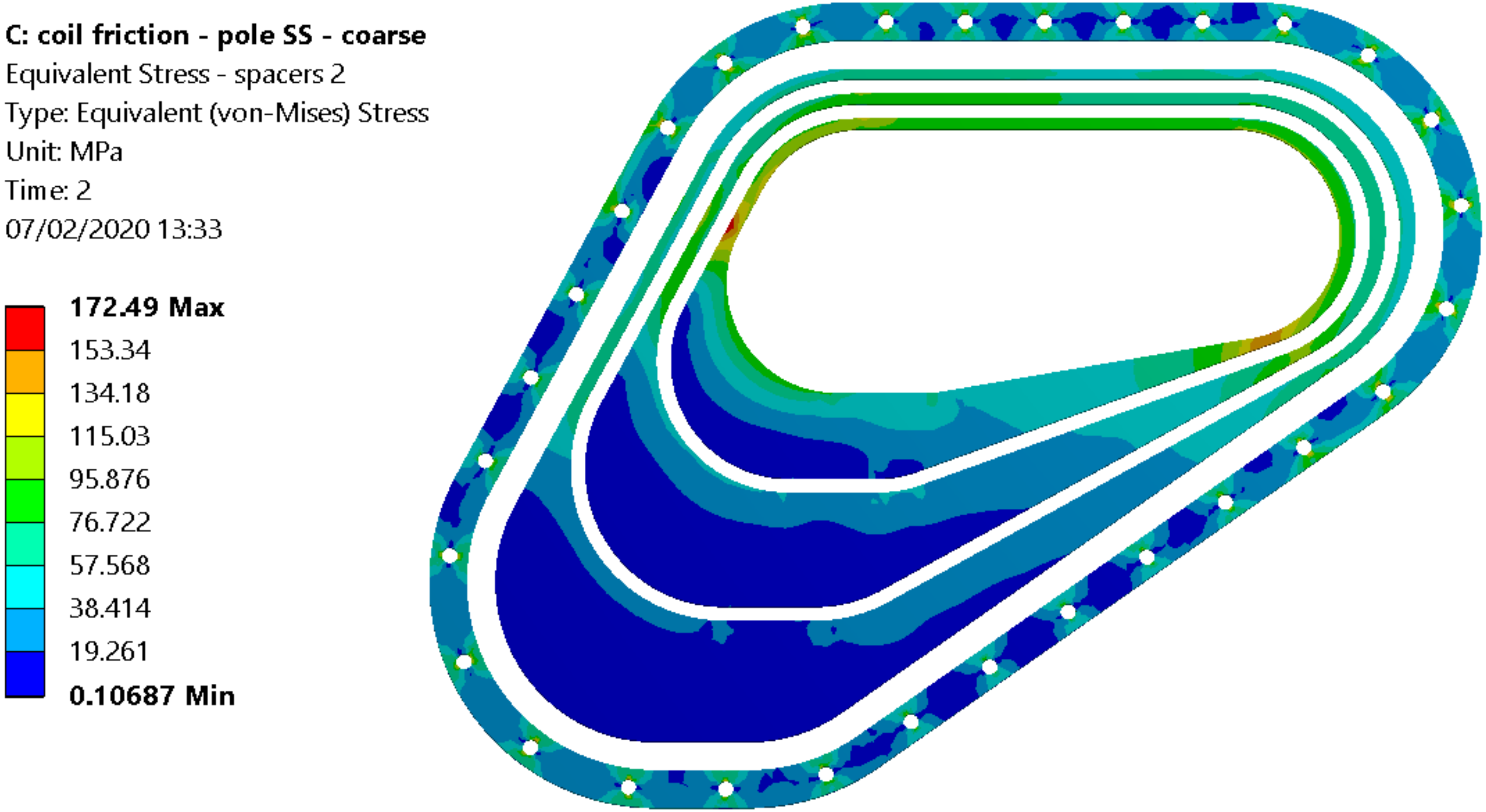
(3) Lorentz forces

Results

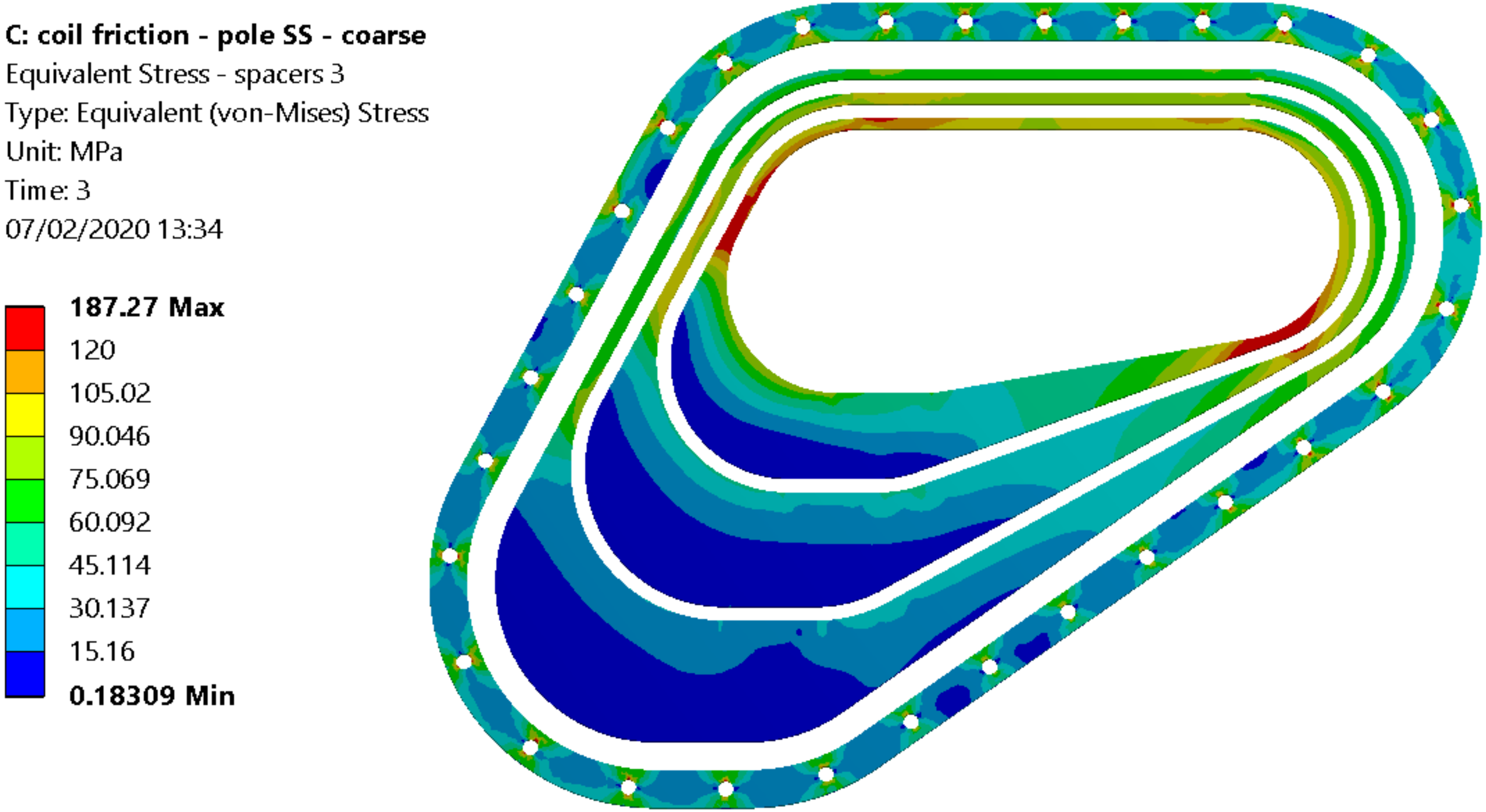
Spacers - equivalent stress (1)



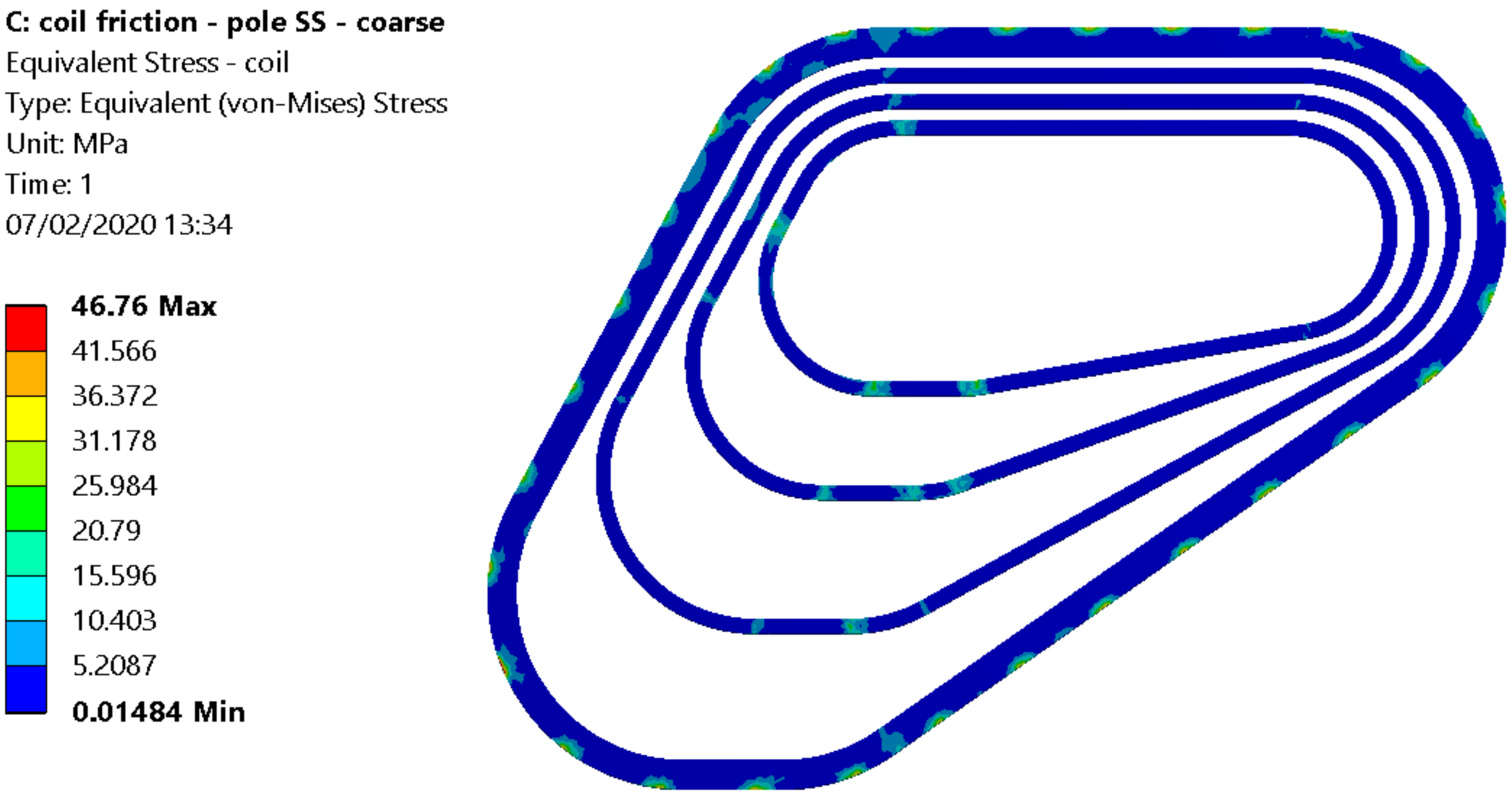
Spacers - equivalent stress (2)



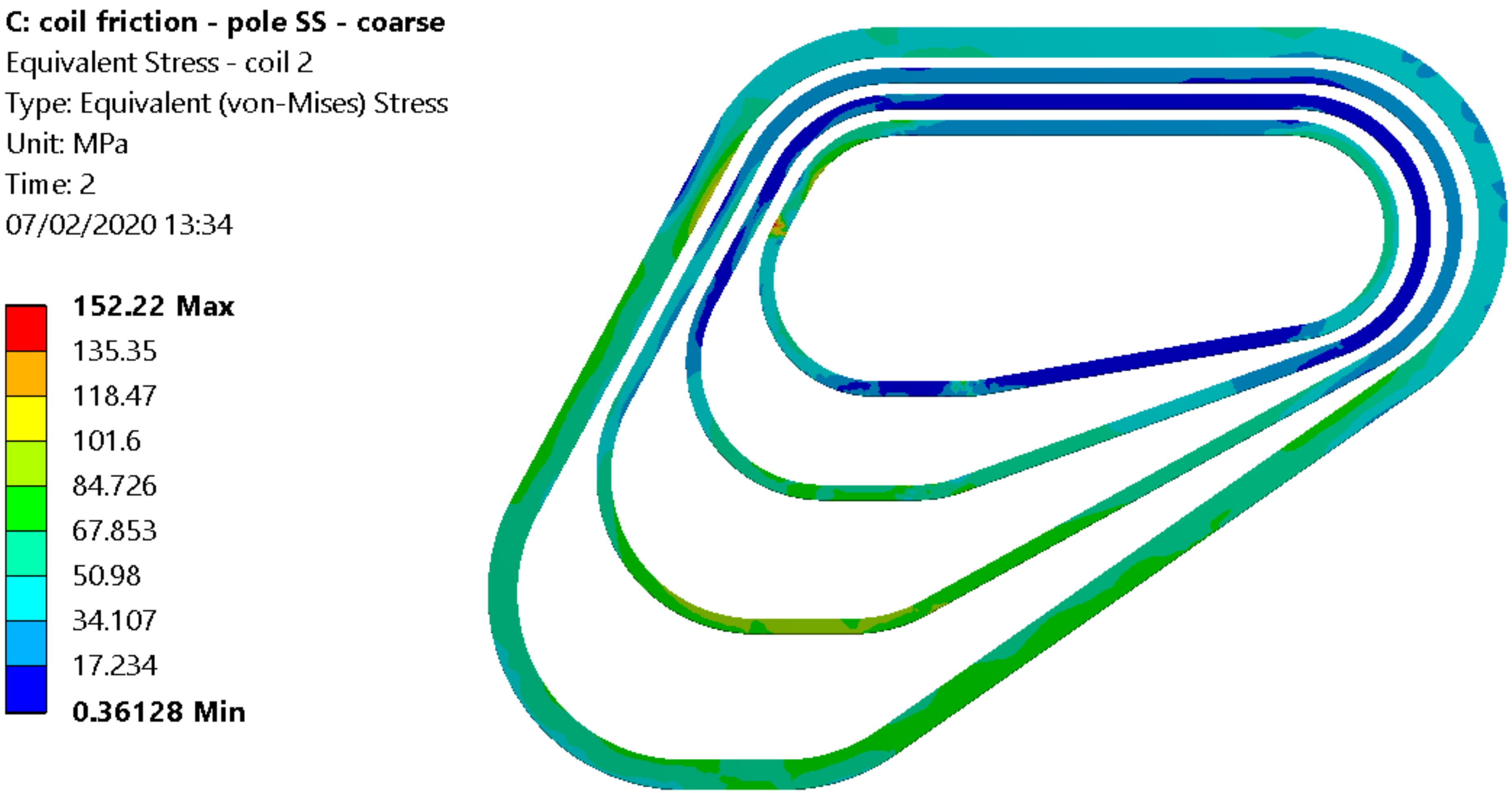
Spacers - equivalent stress (3)



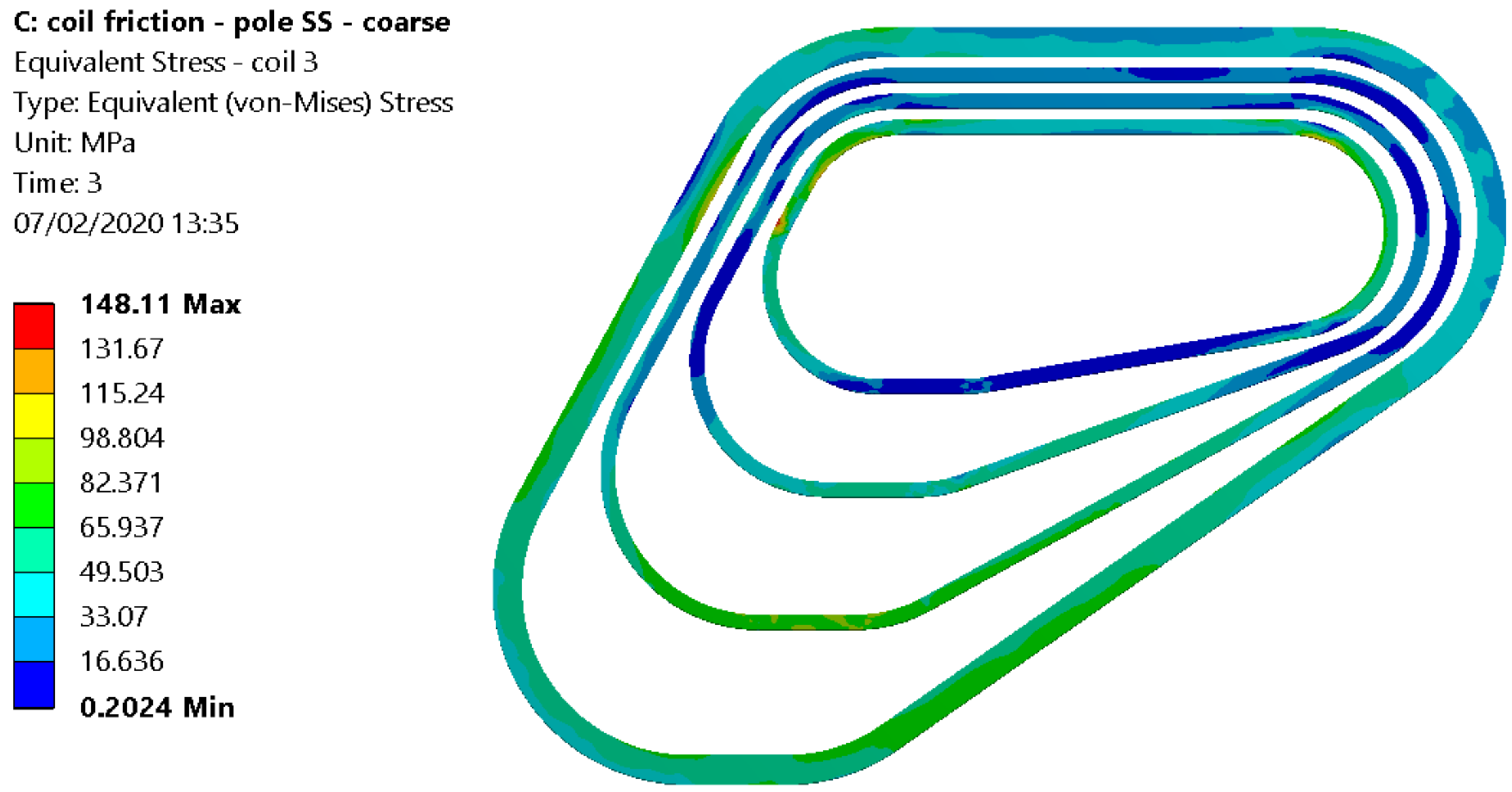
Coils - equivalent stress (1)



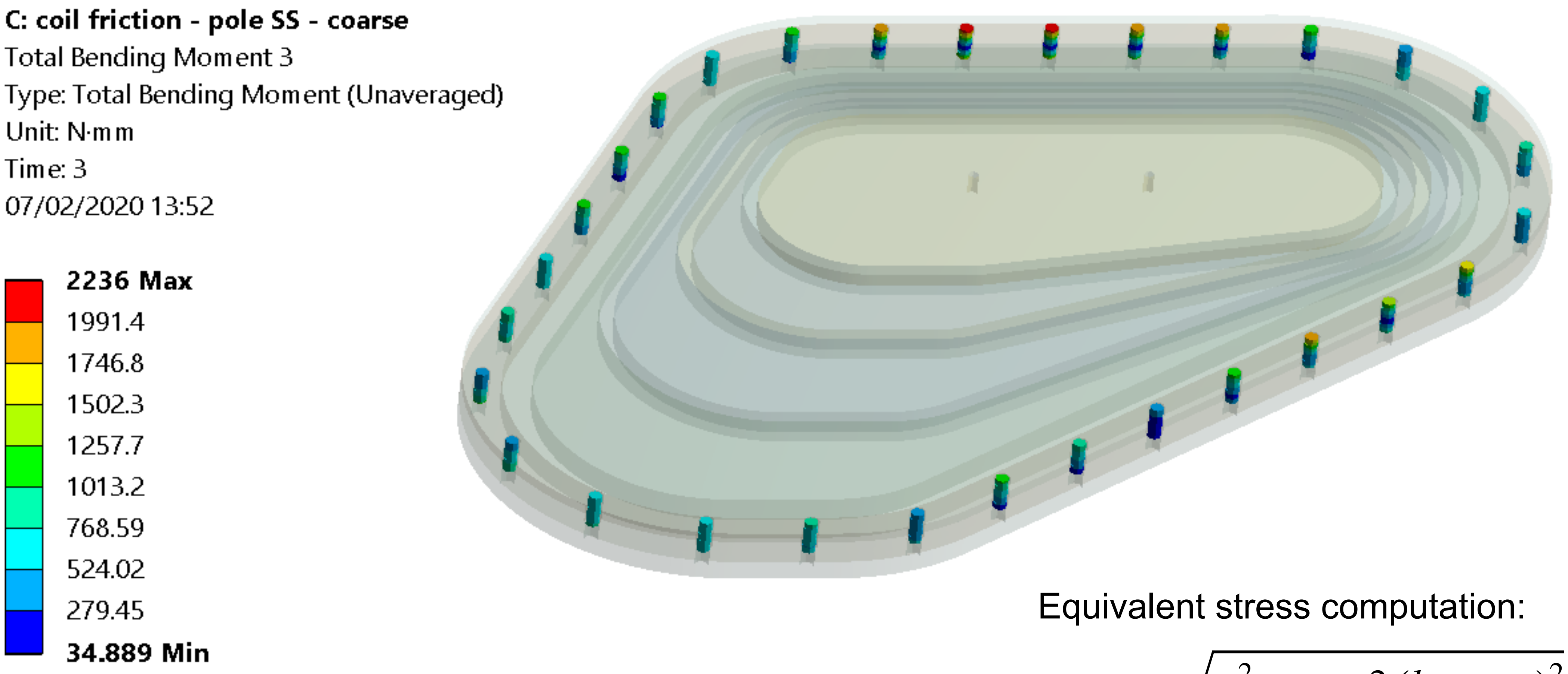
Coils - equivalent stress (2)



Coils - equivalent stress (3)



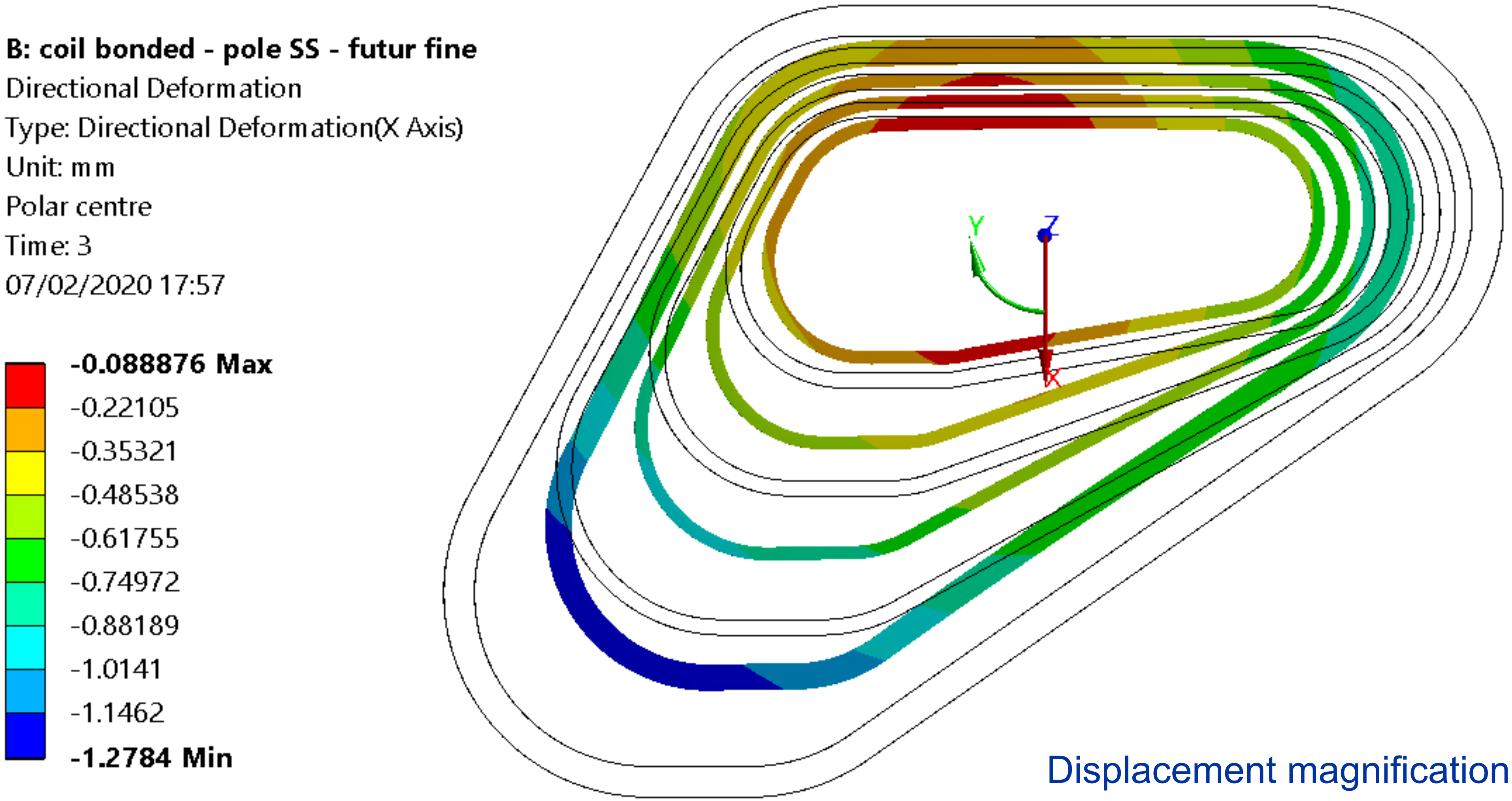
Bolts - bending moment



Equivalent stress computation:

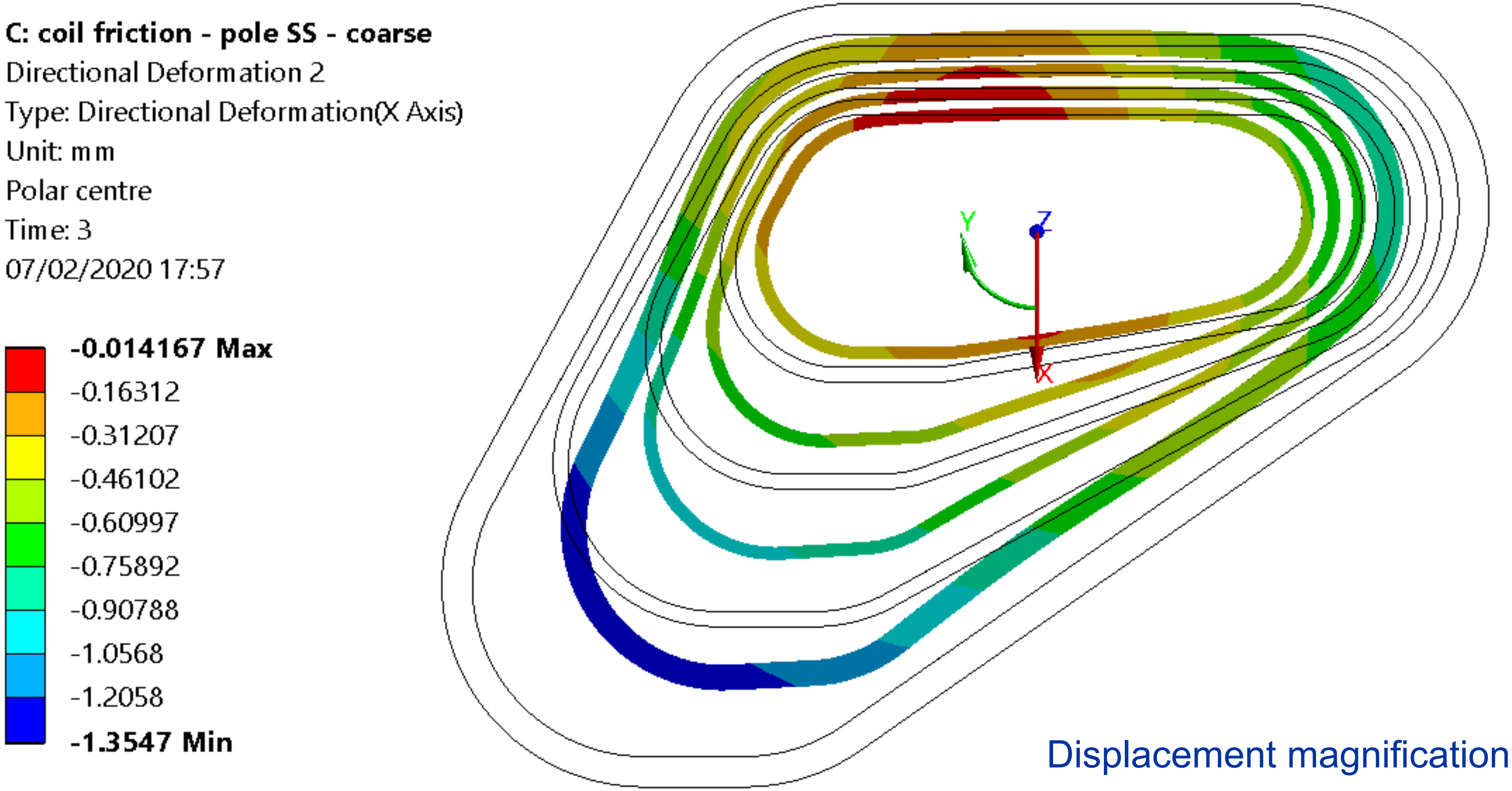
$$\sigma_{red,B} = \sqrt{\sigma_{zb,max}^2 + 3\,(k_t \cdot \tau_{max})^2}$$

Radial displacement - bonded - SS pole



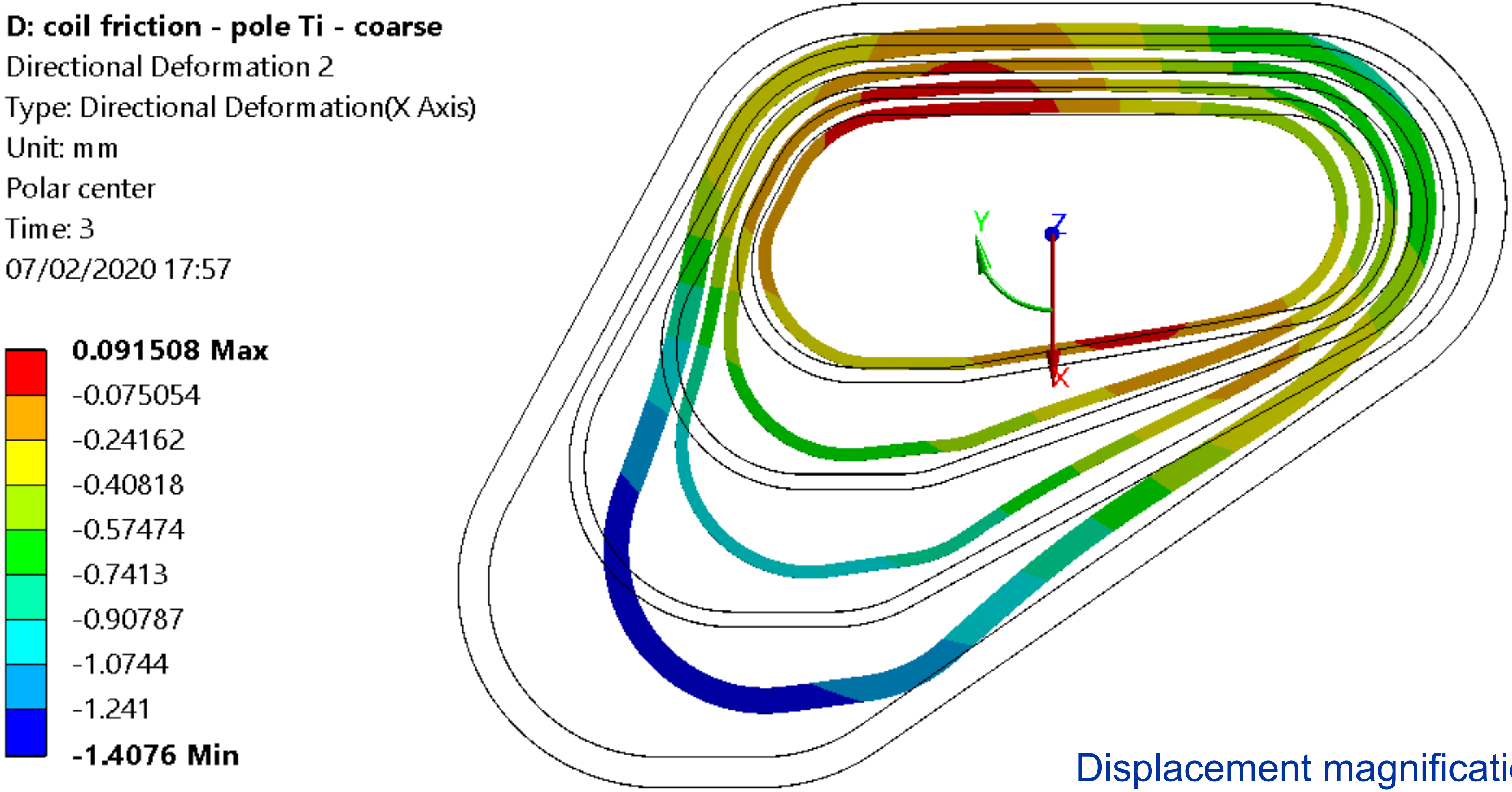
Displacement magnification factor: 50

Radial displacement - frictional - SS pole



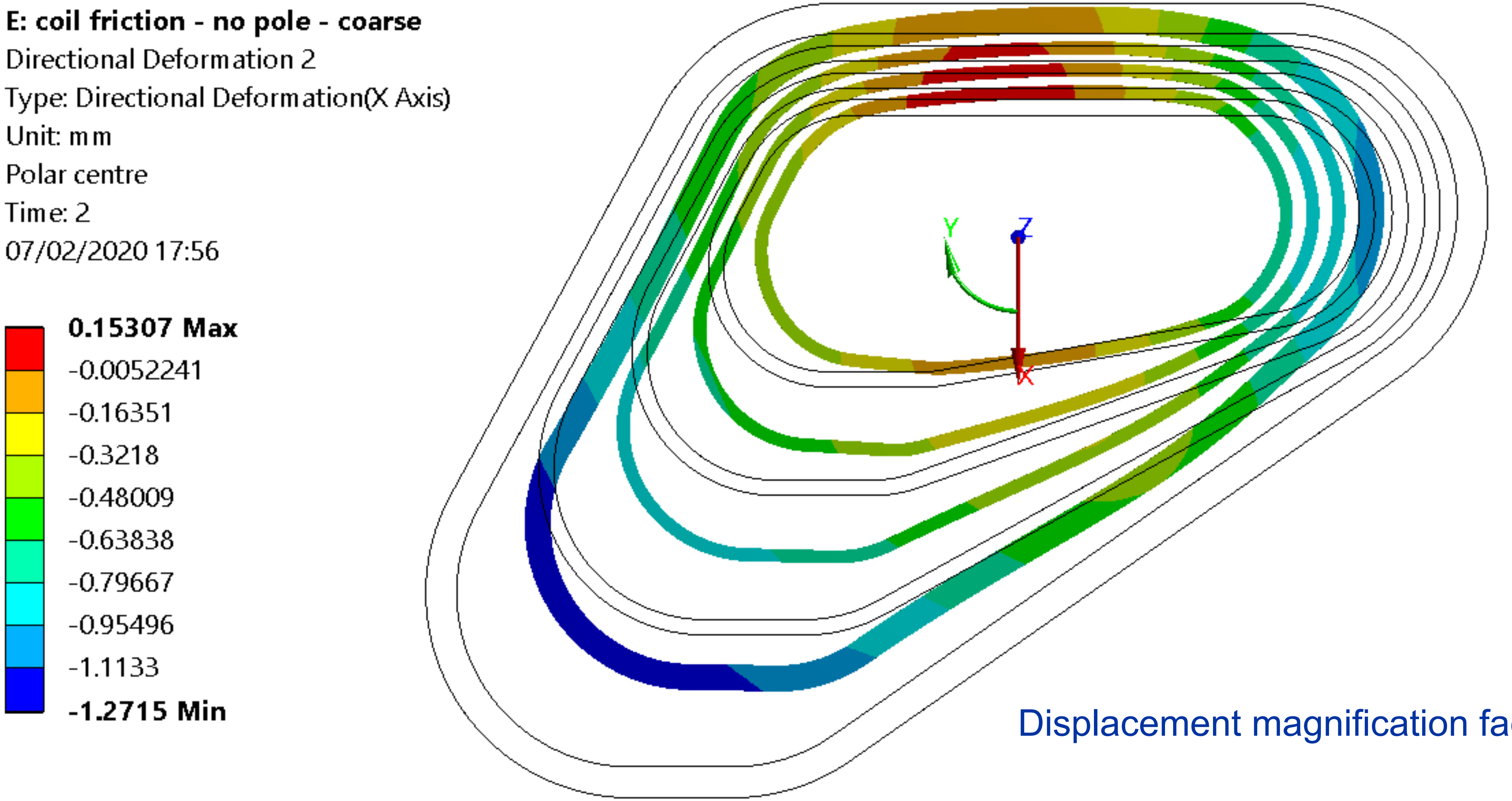
Displacement magnification factor: 50

Radial displacement - frictional - Ti pole



Displacement magnification factor: 50

Radial displacement - frictional - no pole



Displacement magnification factor: 50

Configuration comparison

		Coil frictional SS pole	Coil bonded SS pole	Coil frictional Ti pole	Coil frictional No pole
Coils	Mean stress [MPa]	38	40	66	39
	Max stress [MPa]	148	117	324	97
	Max displacement [mm]	1.45	1.37	1.61	1.37
Spacers	Mean stress [MPa]	49	53	67	45
	Max stress [MPa]	187	207	303	183
Bolts	Safety factor	1.62	1.63	1.64	1.62
Pole	Mean pressure [MPa]	6	12	29	
	Max pressure [MPa]	86	111	140	

Take-home message

- Stress state mainly lead by the **cool-down**
- **Preload** seems introducing unreasonably **high-stress** level
- **Stiffness** of spacers overestimated by omitting **grade jumps**
- Shear stress at **contact interfaces** $\sim$ 20 MPa $\rightarrow$ **resin cannot withstand contact**
- Future investigation of configurations with **less preload** $\rightarrow$ spacers in SS

home.cern