Simulation results of the design iteration

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Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Outline

- Introduction
- Model Description
  - Geometry & Materials
  - Boundary conditions
  - Contacts
- Torque load definition
- Model checks
- Results of Present ID VS Shorter ID
- Results of Present ID using 20 GPa VS 15 GPa cables
- Work in progress
- Conclusions

Introduction

- As solution to improve MCBXFB performance shorter ID coils have been proposed.

- The goals of the ongoing simulations are:
  - Understand why the inner dipole coil heads are the cause of the majority of quenches.
  - Evaluate if shorter ID coils could improve performance.

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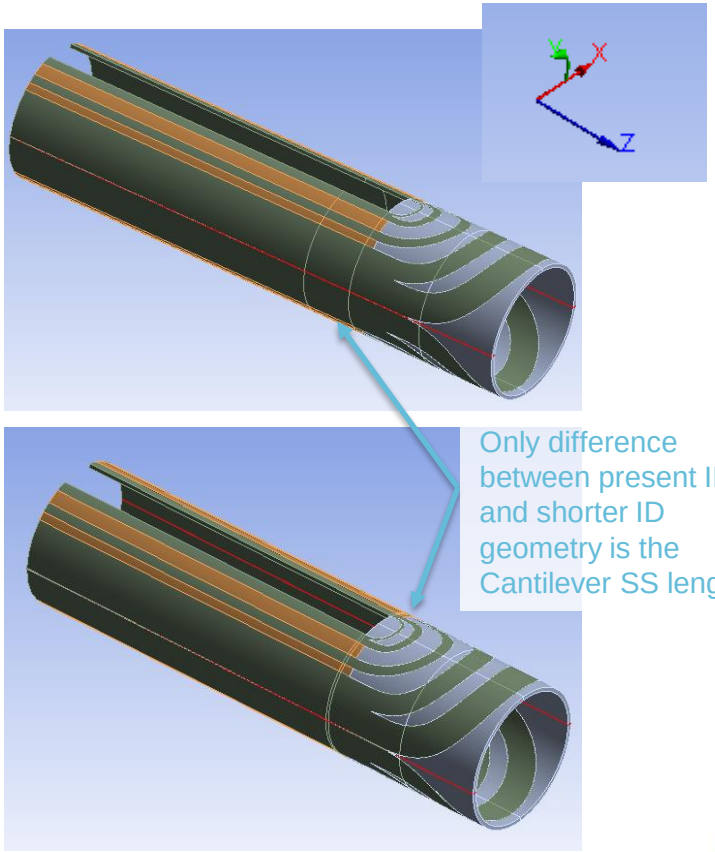
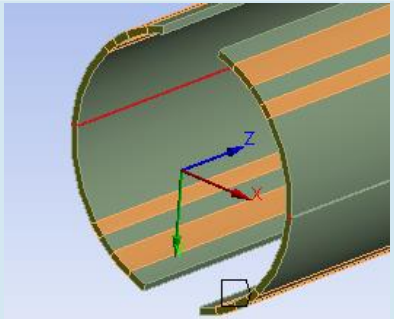
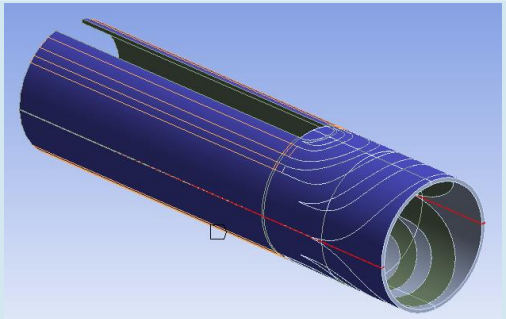
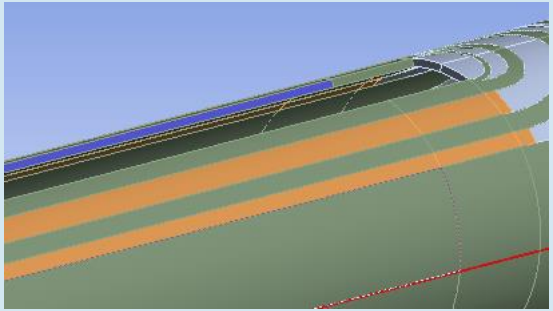
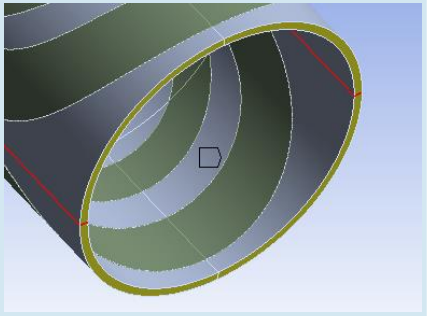
Geometry & materials

- Only ID inner layer has been modelled for the sake of simplicity.
- Real endspacers geometry was used to generate the corresponding coils and wedges by solid Boolean operations.
- Full 4 quadrant model is used to assure precision. Several half symmetry application options have been tested and discarded by the moment.
- Model is divided azimuthally in quadrants and in 4 sections along Z direction to ease torque load application:
  - Fasten straight section (SS)
  - Loose part of the straight section (Cantilever SS)
  - Head beginning
  - Head end
- Isotropic materials used:
  - Cables: 20 Gpa
  - Wedges: 130 Gpa
  - Endspacers: 193 Gpa
  - Midplane Kapton: 2.5 Gpa

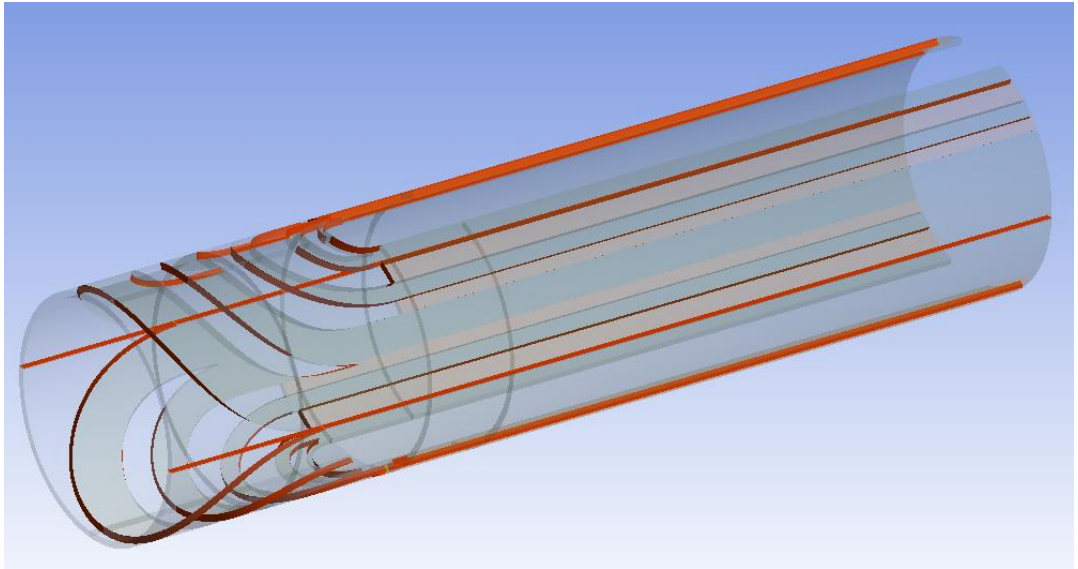


Boundary contitions

Mid-dipole displacement along Z = 0	Radial displacement of outer face = 0
Half dipole symmetry 	Collaring restriction 
SS poles fixed at Q1 and Q3	**Σ Z Rot Dipole endface = 0**
Torque locking provided by the collars 	Fixed end (it can move along Z but not rotate) 

Contacts

- Define between the different bodies: wedges, cables, endpacers and midplane kapton.
- Same body interfaces share topology.
- All the contacts are considered bonded as a first approximation to the problem.



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Torque load distribution along Z

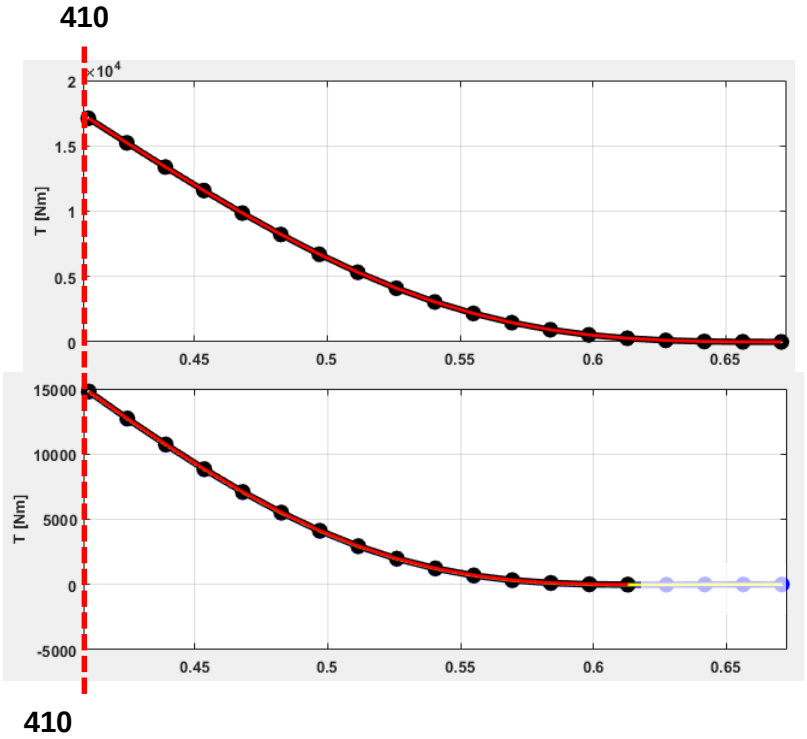
Straight Section

Present ID

M_{SS} = 137 kNm/m

Shorter ID

M_{SS} = 151 kNm/m



- EM Torque is the only load applied to the model (Room temperature is considered)
- 1st assumption: Coil cables suffer a torque profile like the one obtained at the magnet axis.
- This torque profile is simplified by a polyline so constant torque can be applied at the different dipole sections along Z direction

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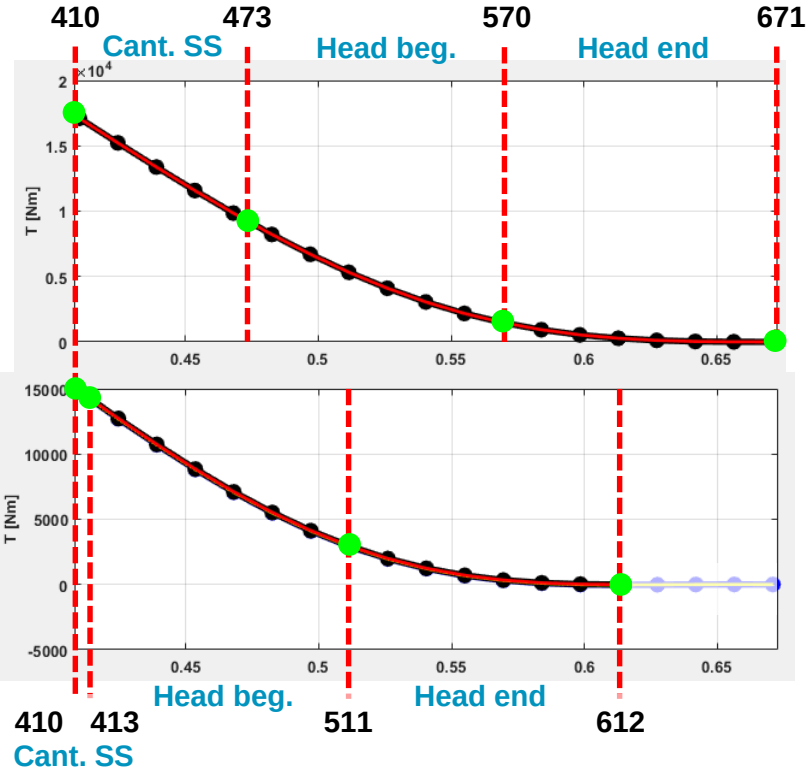

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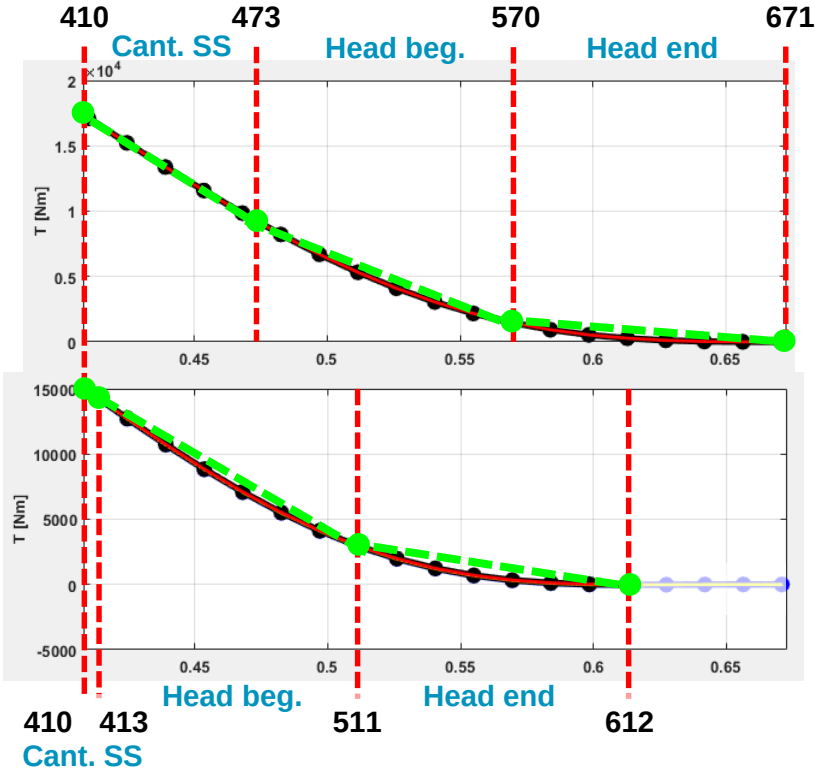

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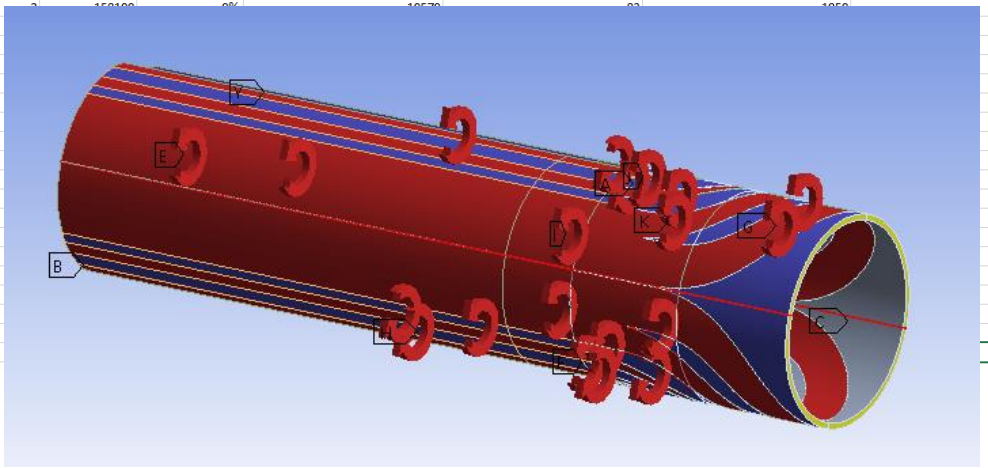
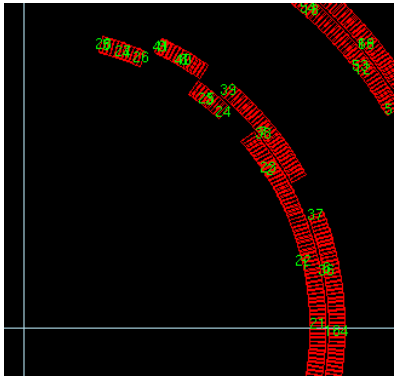
- 1st assumption: Coil cables suffer a torque profile like the one obtained at the magnet axis.
- This torque profile is simplified by a polyline so constant torque can be applied at the different dipole sections along Z direction

Azimuthal torque load distribution

Cable block	F_y [N]	Total Torque [%]	SS model torque (410 mm) [Nm]	Cantilever SS Torque	Head Beg Torque [Nm]	Head end Torque [Nm]
1	-58570	3%	3919	31	722	190
2	-59300	3%	3968	31	731	193
3	-256800	14%	17183	135	3167	835
1	30380	-2%	-2033	-16	-375	-99
2	5934	0%	-397	-3	-73	-19
3	-126200	7%	8444	66	1556	410
1	-71370	4%	4776	38	880	232
						514
						448
						-59
						68
						275
						-217
						-66
						196
						388
						663
						666
						-37
						-120
						202
						82
						655
						574
All						1218
All						292





- 2nd assumption: Torque distributes among the coil cable blocks as in a 2D Roxie simulation.
- Torque load is proportionally computed for each coil block and sector and then applied in the model.

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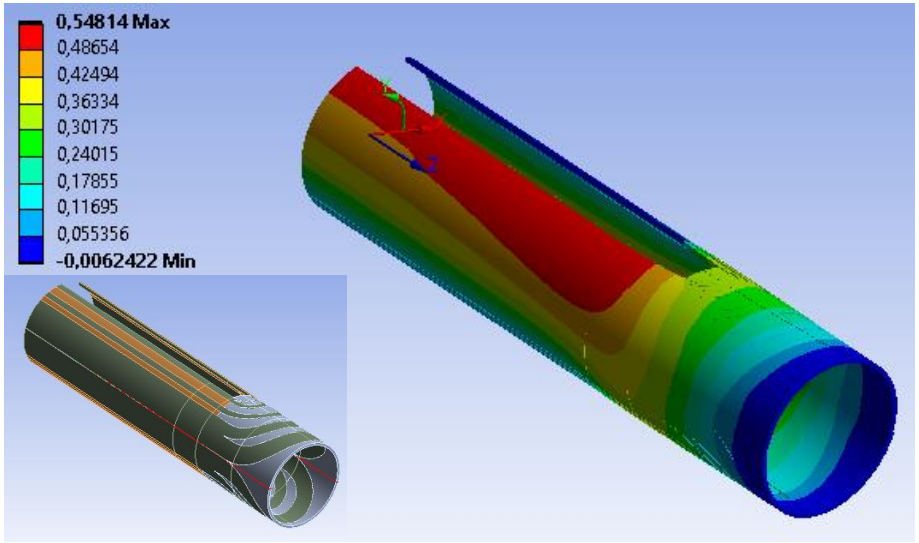
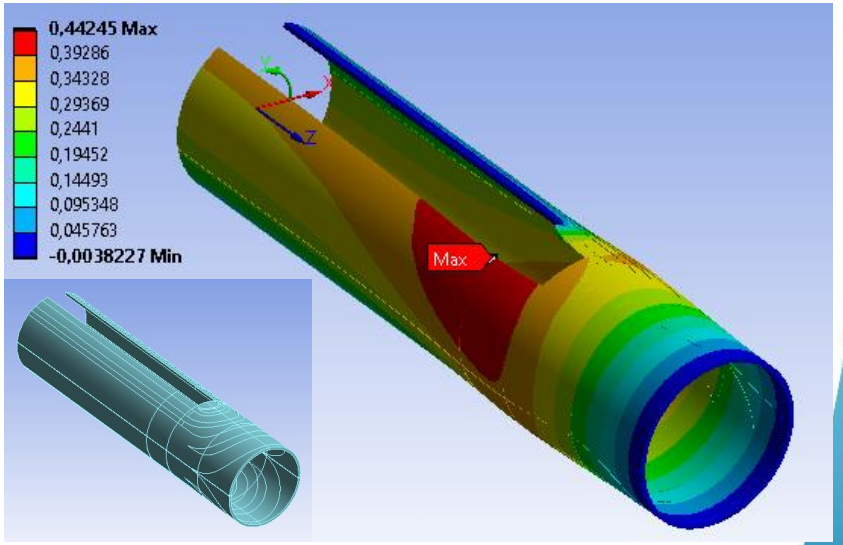
Smeared-out dipole (35 Gpa)

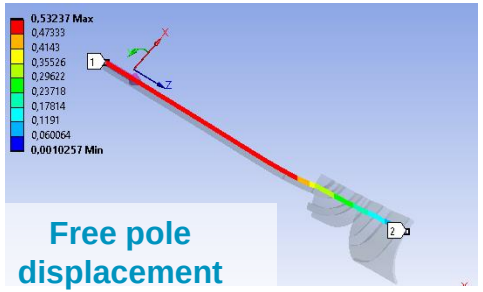
- Smeared out results for a 35 GPa dipole are not far from the ones obtained with real materials.

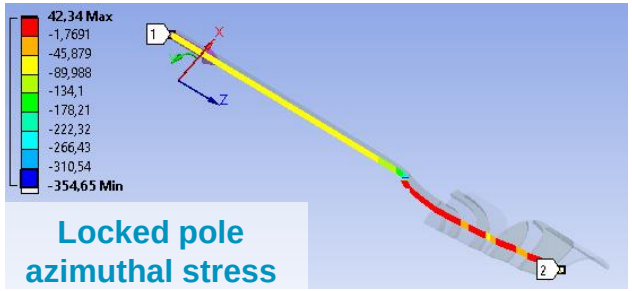


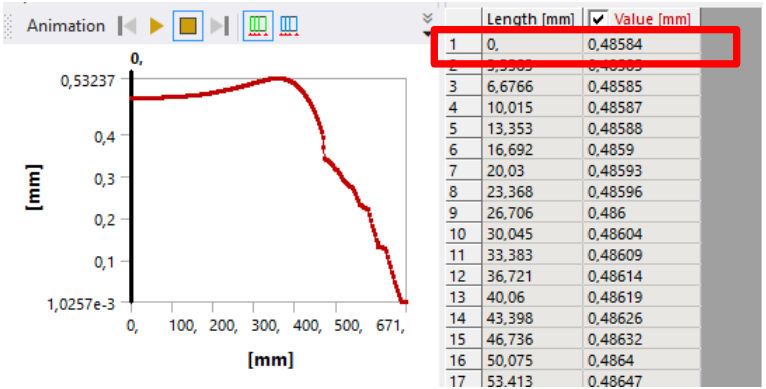


Stress at locked pole and displacement in the free one

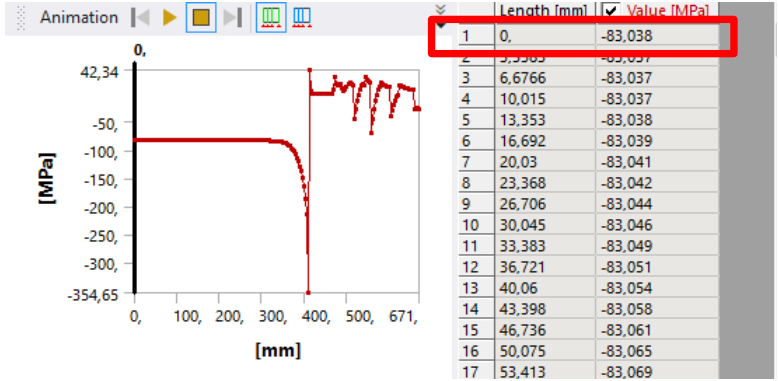
- Coherent with the arc length and smeared out straight section of 30 GPa







	Length [mm]	Value [mm]
1	0,	0,48584
3	6,6766	0,48585
4	10,015	0,48587
5	13,353	0,48588
6	16,692	0,4859
7	20,03	0,48593
8	23,368	0,48596
9	26,706	0,486
10	30,045	0,48604
11	33,383	0,48609
12	36,721	0,48614
13	40,06	0,48619
14	43,398	0,48626
15	46,736	0,48632
16	50,075	0,4864
17	53,413	0,48647



	Length [mm]	Value [MPa]
1	0,	-83,038
3	6,6766	-83,037
4	10,015	-83,037
5	13,353	-83,038
6	16,692	-83,039
7	20,03	-83,041
8	23,368	-83,042
9	26,706	-83,044
10	30,045	-83,046
11	33,383	-83,049
12	36,721	-83,051
13	40,06	-83,054
14	43,398	-83,058
15	46,736	-83,061
16	50,075	-83,065
17	53,413	-83,069

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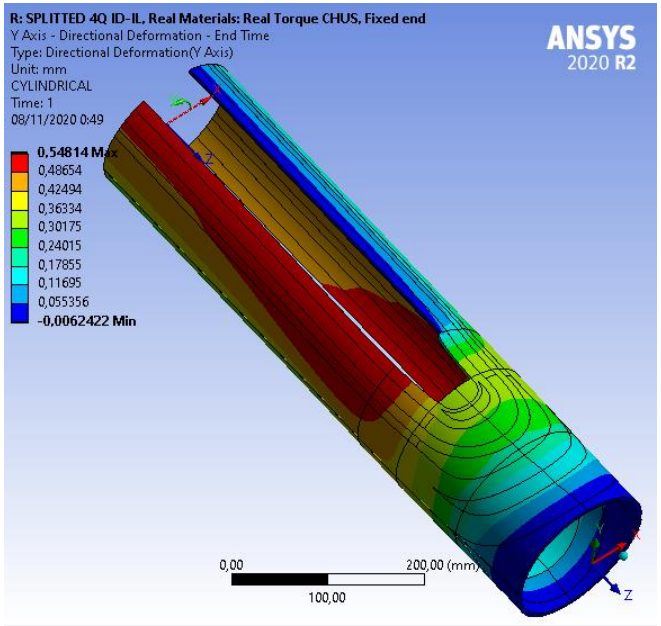
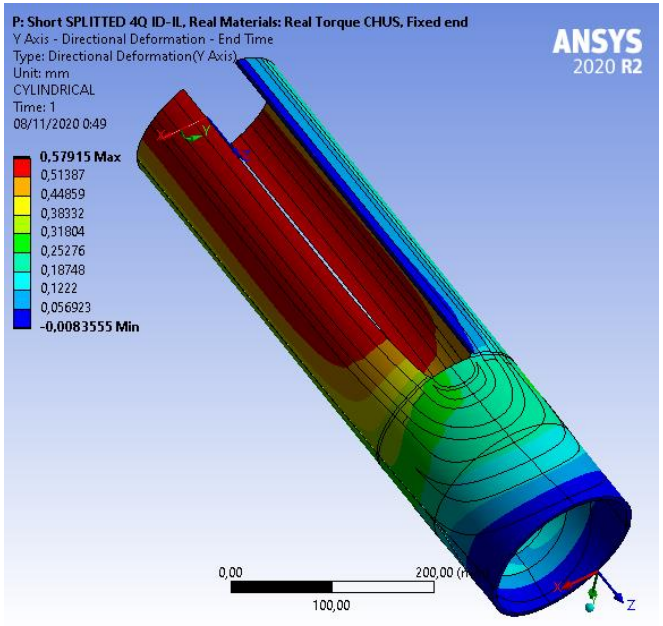
All displacements have been graphically multiplied **x40**

Azimuthal deformation

Present ID-IL

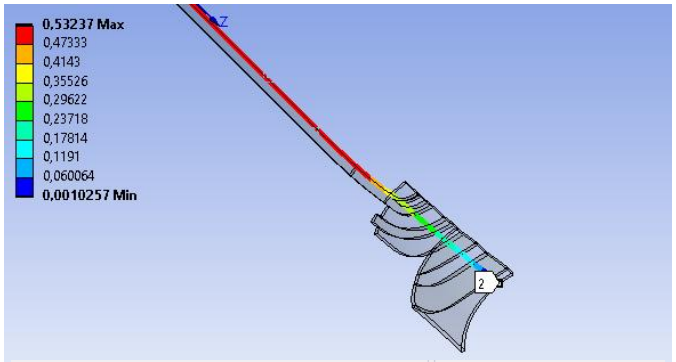


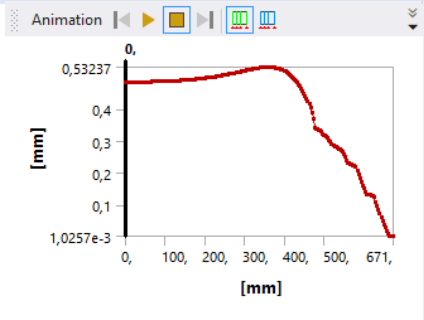
Shorter ID-IL



Path along Free pole: Azimuthal displacement

Present ID-IL





	Length [mm]	Value [mm]
1	0,	0,48584
2	3,3383	0,48585
3	6,6766	0,48585
4	10,015	0,48587
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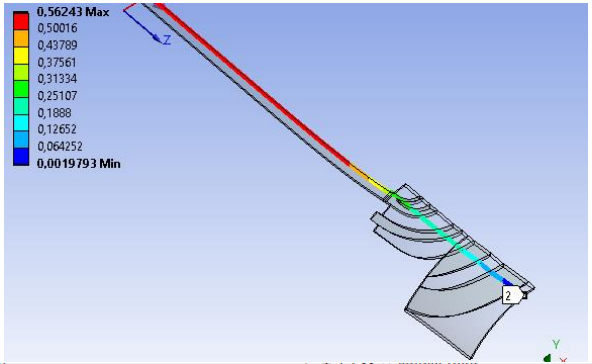
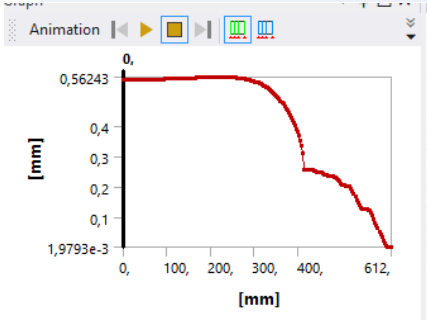
Shorter ID-IL

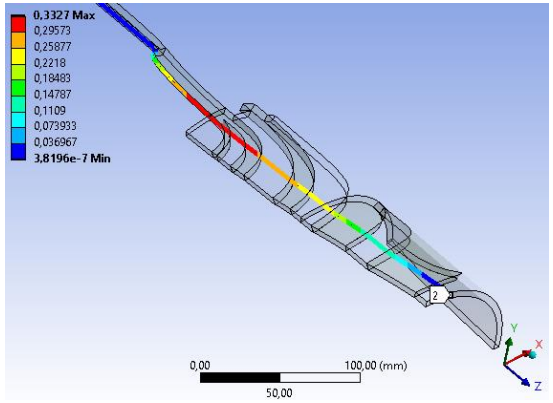


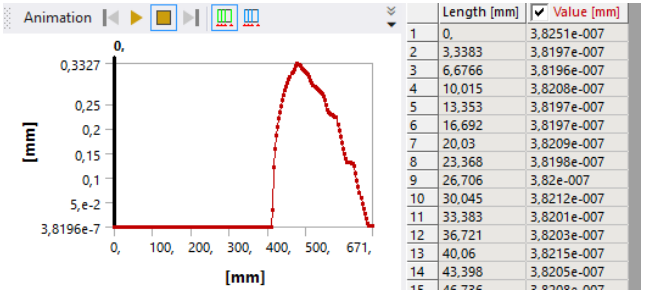


	Length [mm]	Value [mm]
1	0,	0,55393
2	3,0448	0,55394
3	6,0896	0,55394
4	9,1343	0,55396
5	12,179	0,55397
6	15,224	0,55399
7	18,269	0,55402
8	21,313	0,55405
9	24,358	0,55409
10	27,403	0,55413
11	30,448	0,55417
12	33,493	0,55422
13	36,537	0,55428
14	39,582	0,55433
15	42,627	0,5544

Path along Locked pole: Azimuthal displacement

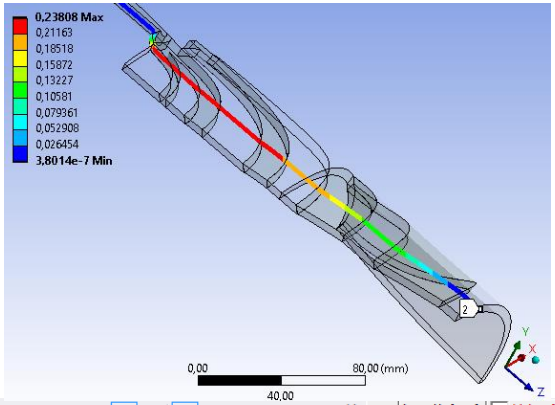
Present ID-IL

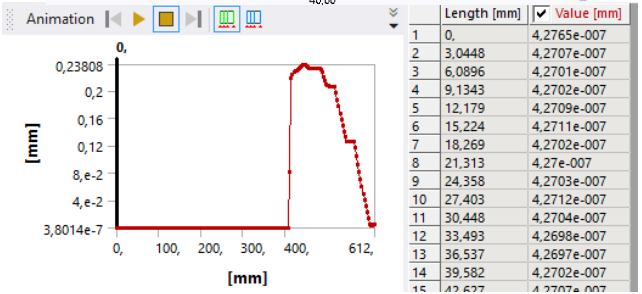




	Length [mm]	Value [mm]
1	0,	3,8251e-007
2	3,3383	3,8197e-007
3	6,6766	3,8196e-007
4	10,015	3,8208e-007
5	13,353	3,8197e-007
6	16,692	3,8197e-007
7	20,03	3,8209e-007
8	23,368	3,8198e-007
9	26,706	3,82e-007
10	30,045	3,8212e-007
11	33,383	3,8201e-007
12	36,721	3,8203e-007
13	40,06	3,8215e-007
14	43,398	3,8205e-007

Shorter ID-IL

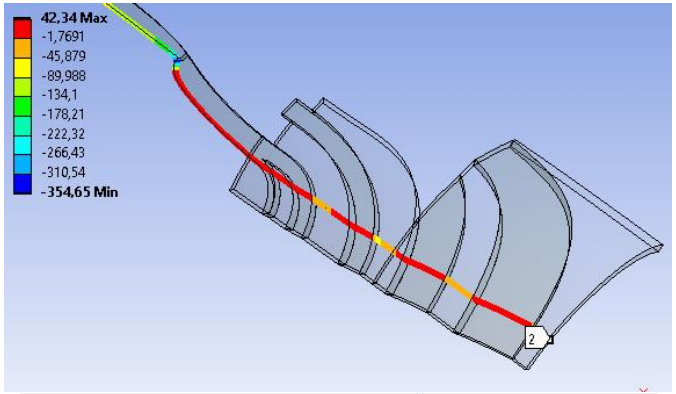


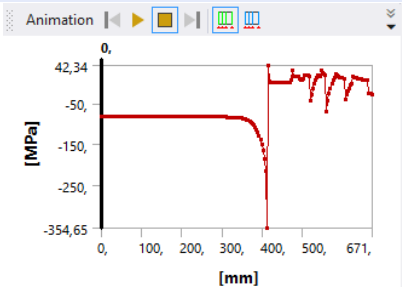


	Length [mm]	Value [mm]
1	0,	4,2765e-007
2	3,0448	4,2707e-007
3	6,0896	4,2701e-007
4	9,1343	4,2702e-007
5	12,179	4,2709e-007
6	15,224	4,2711e-007
7	18,269	4,2702e-007
8	21,313	4,27e-007
9	24,358	4,2703e-007
10	27,403	4,2712e-007
11	30,448	4,2704e-007
12	33,493	4,2698e-007
13	36,537	4,2697e-007
14	39,582	4,2702e-007

Path along Locked pole: Azimuthal Stress

Present ID-IL





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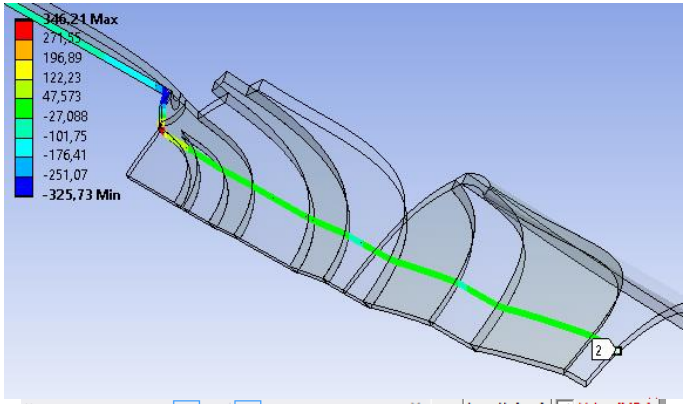
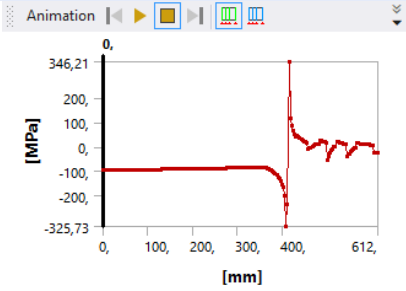
10	30,045	-83,046
11	33,383	-83,049
12	36,721	-83,051
13	40,06	-83,054
14	43,398	-83,058

Shorter ID-IL





	Length [mm]	Value [MPa]
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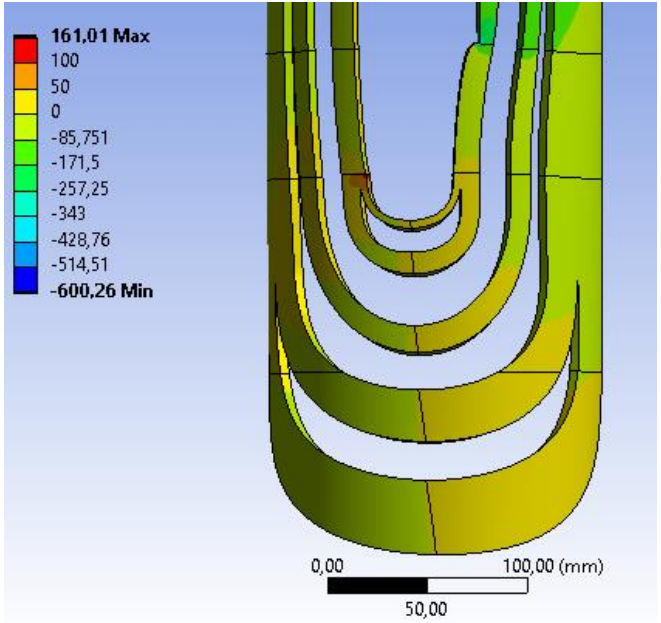
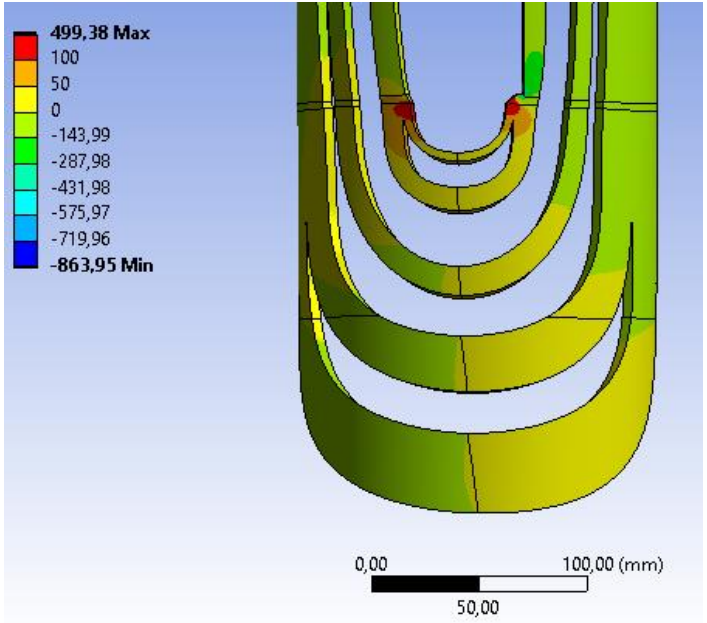
3	6,0896	-92,843
4	9,1343	-92,843
5	12,179	-92,842
6	15,224	-92,842
7	18,269	-92,841
8	21,313	-92,84
9	24,358	-92,839
10	27,403	-92,838
11	30,448	-92,836
12	33,493	-92,835
13	36,537	-92,833
14	39,582	-92,831

Cables: Azimuthal Stress

Present ID-IL

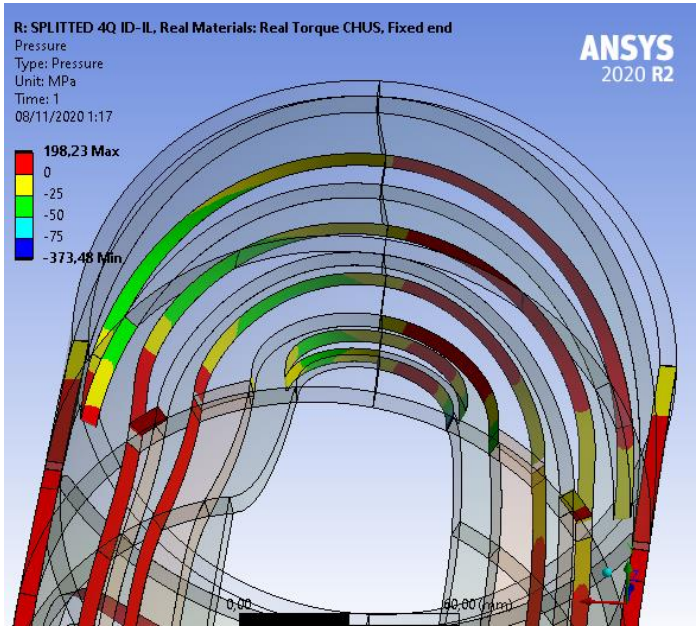


Shorter ID-IL



Contacts: Pressure

Present ID-IL



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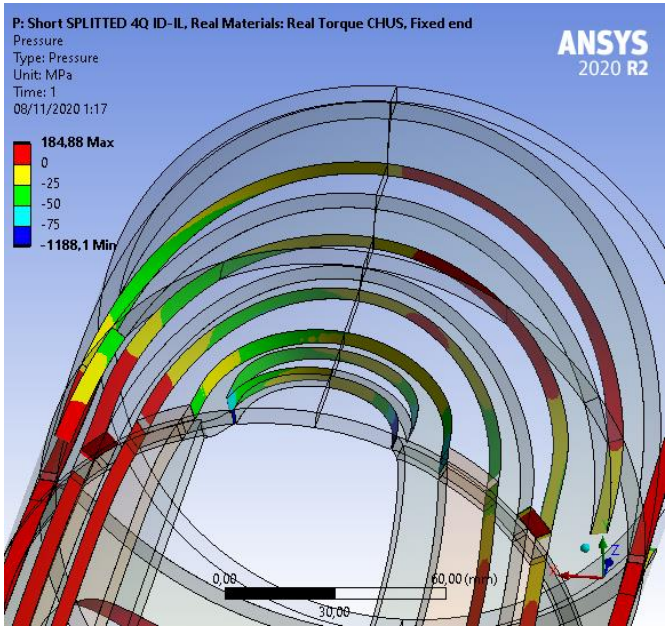

Contacts: Pressure

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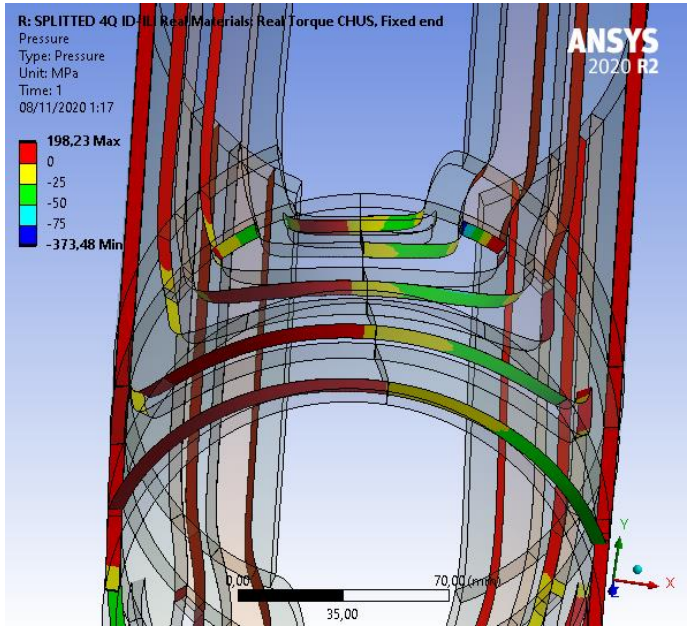
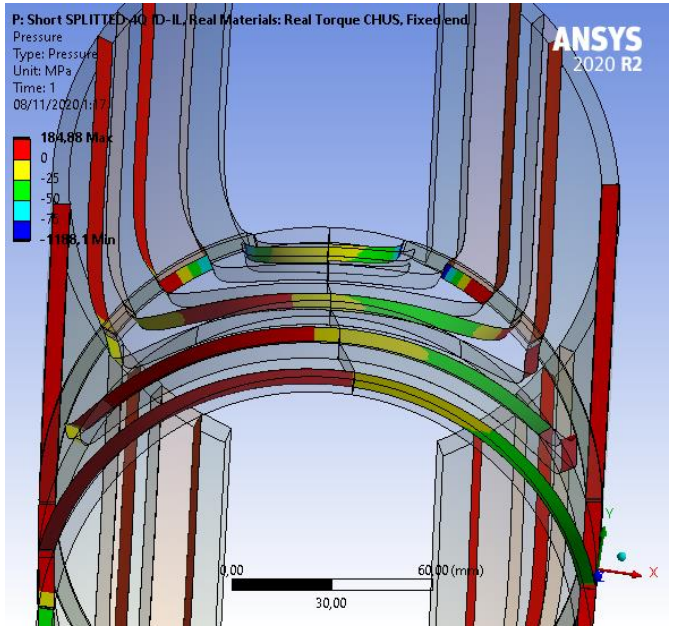
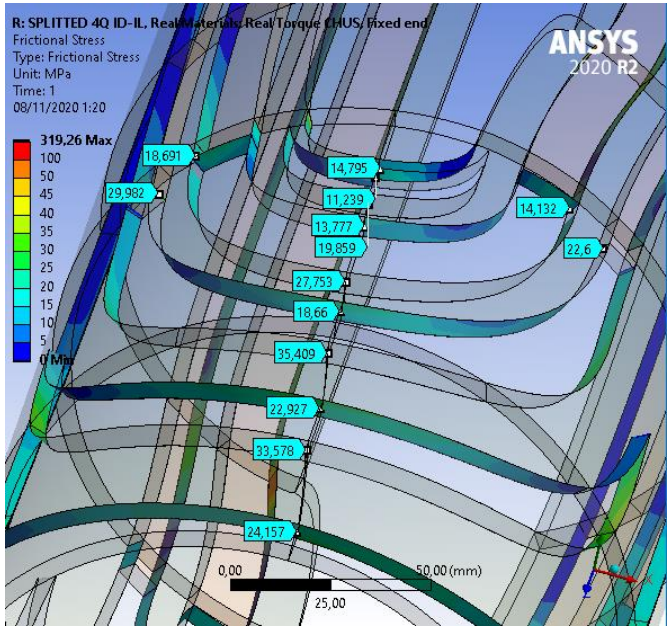


Shorter ID-IL

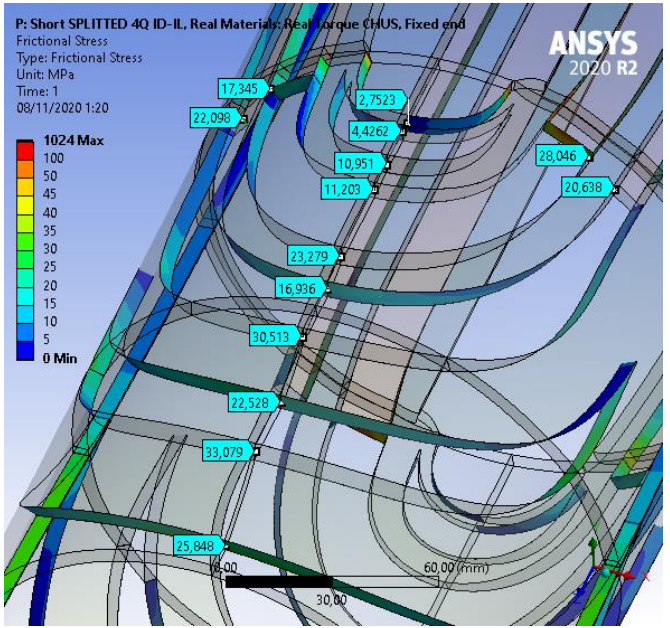


Contacts: Frictional Stress (Mid-coil)

Present ID-IL

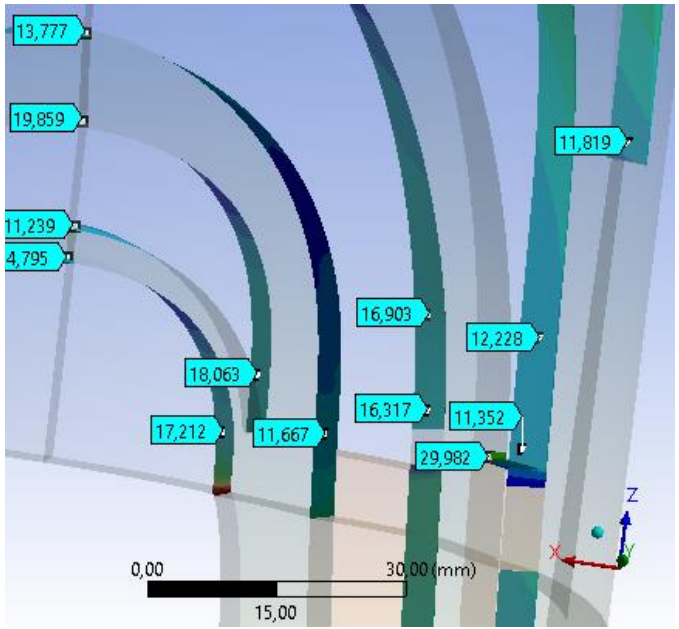


Shorter ID-IL

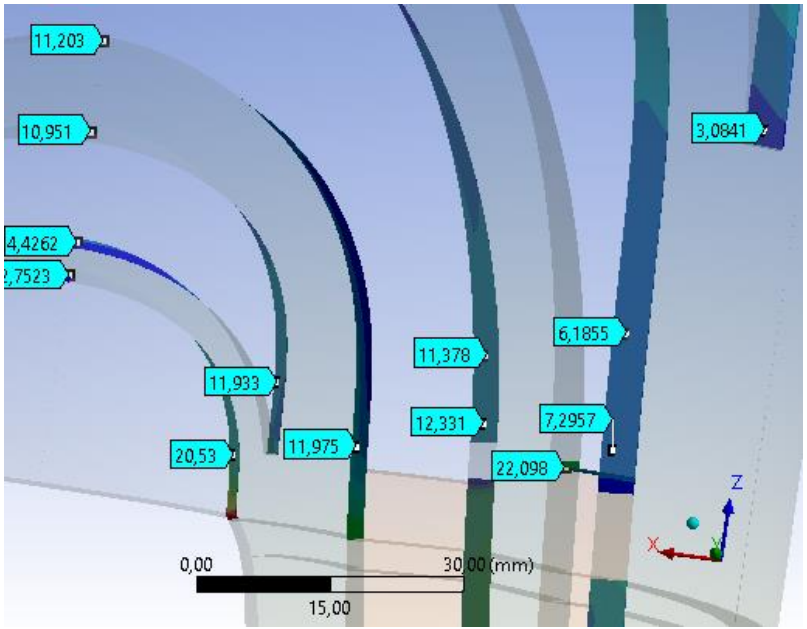


Contacts: Frictional Stress (Endspacers tips)

Present ID-IL



Shorter ID-IL



Outline

- Introduction
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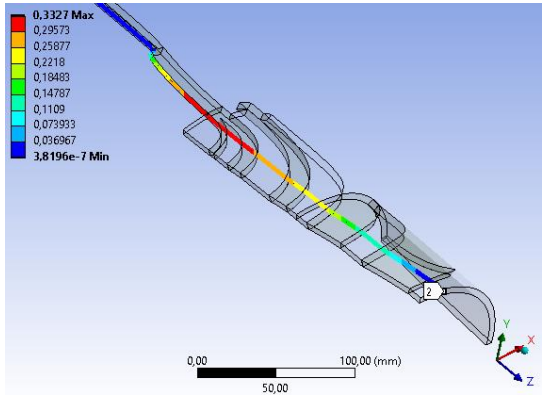
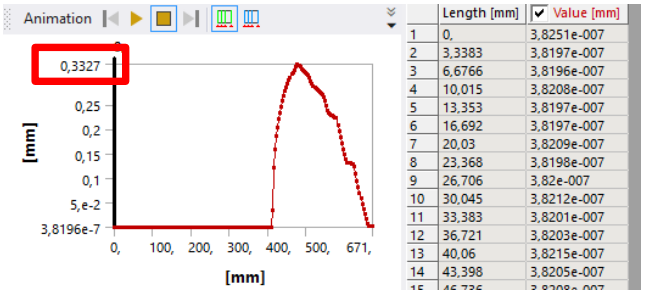
All displacements have been graphically multiplied **x40**

Path along Locked pole: Azimuthal displacement

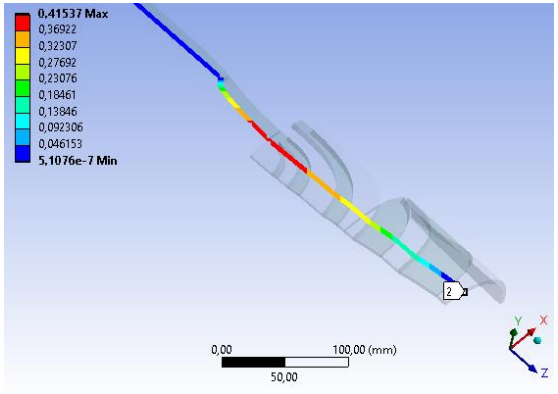
Present ID-IL (P1, 20 GPa)

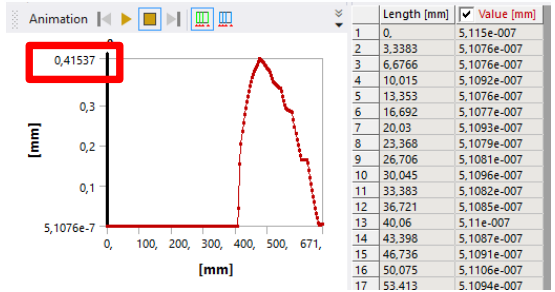




	Length [mm]	Value [mm]
1	0,	3,8251e-007
2	3,3383	3,8197e-007
3	6,6766	3,8196e-007
4	10,015	3,8208e-007
5	13,353	3,8197e-007
6	16,692	3,8197e-007
7	20,03	3,8209e-007
8	23,368	3,8198e-007
9	26,706	3,82e-007
10	30,045	3,8212e-007
11	33,383	3,8201e-007
12	36,721	3,8203e-007
13	40,06	3,8215e-007
14	43,398	3,8205e-007

Present ID-IL (P2, 15 GPa)





	Length [mm]	Value [mm]
1	0,	5,115e-007
2	3,3383	5,1076e-007
3	6,6766	5,1076e-007
4	10,015	5,1092e-007
5	13,353	5,1076e-007
6	16,692	5,1077e-007
7	20,03	5,1093e-007
8	23,368	5,1079e-007
9	26,706	5,1081e-007
10	30,045	5,1096e-007
11	33,383	5,1082e-007
12	36,721	5,1085e-007
13	40,06	5,11e-007
14	43,398	5,1087e-007
15	46,736	5,1091e-007
16	50,075	5,1106e-007
17	53,413	5,1094e-007

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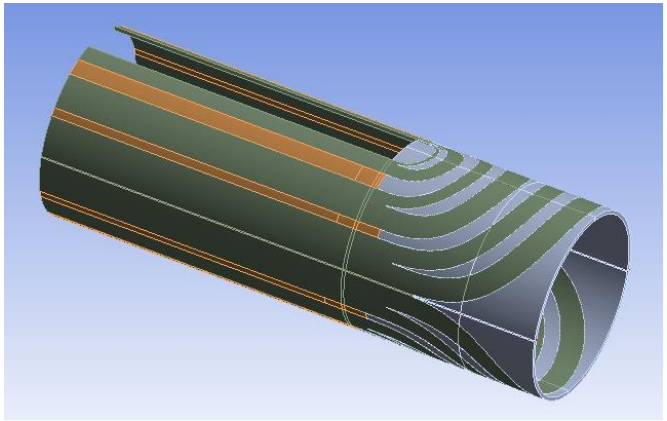
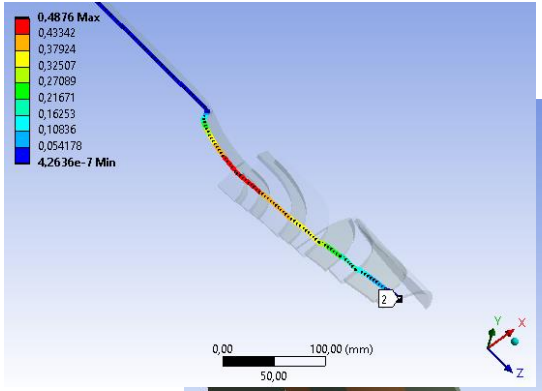
Work in progress

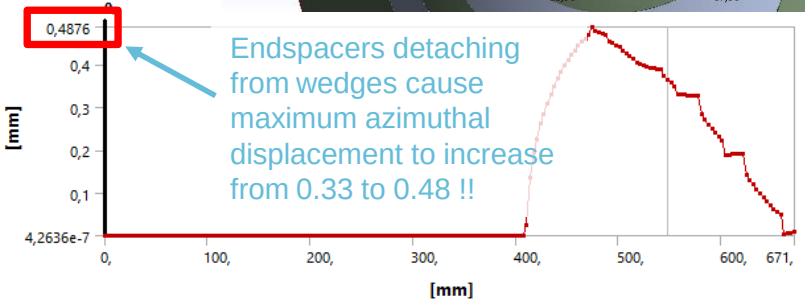
- Outer Dipole Inner Layer model.
  - Goal: Compare displacements and stress between both dipole heads.



Work in progress

- Outer Dipole Inner Layer model.
  - Goal: Compare displacements and stress between both dipole heads.
- Assessment of changes in the model:
  - Frictionless contact at midplane Kapton while coupling Z displacements at dipole endface.
  - Frictionless contacts at wedges/endspacer interfaces.
  - Include pole preload.





Endspacers detaching from wedges cause maximum azimuthal displacement to increase from 0.33 to 0.48 !!

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Conclusions

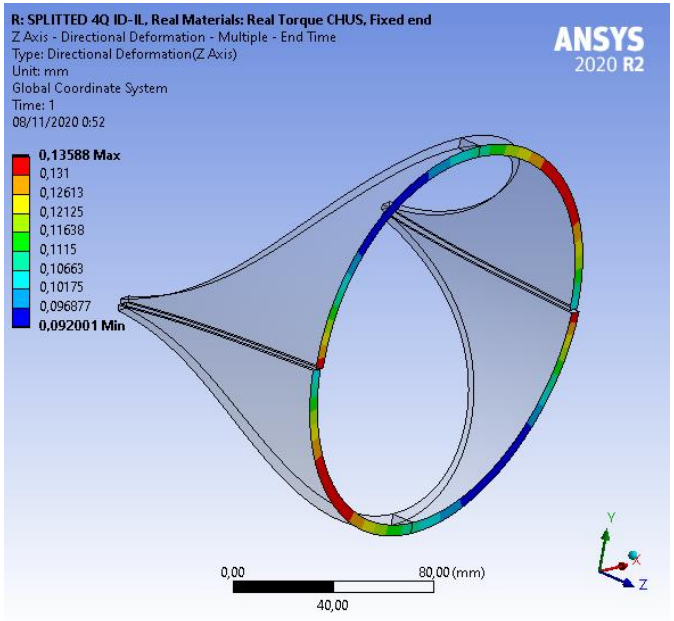
- 4Q ID-IL model has been developed in order to understand ID coil heads behavior under EM torsion.
- First result seems coherent compared with analytic computations.
- Using this model, azimuthal displacements and frictional stress, specially at endspacers tips are lower for a shorter version of the dipole.
- Further analysis is necessary to evaluate model behavior, boundary conditions and contact definitions in order to know if the model results are trustworthy.

Thank you

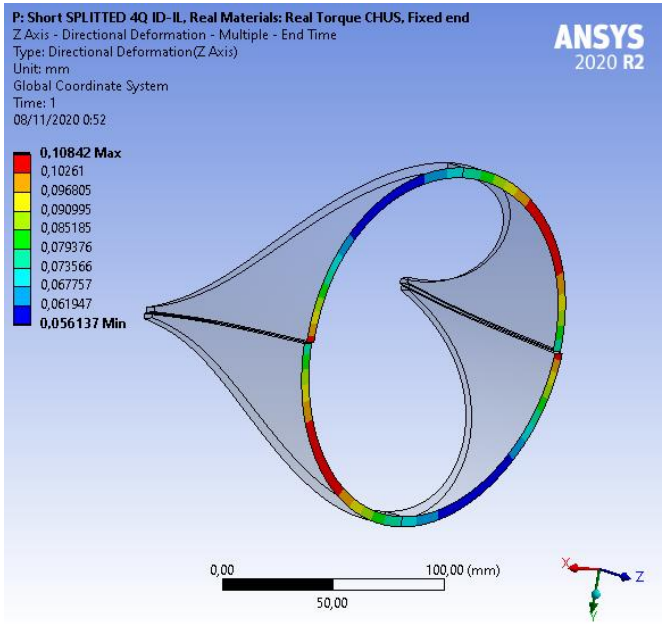
Back-up slides

Z Displacement of saddle endspacers

Present ID-IL

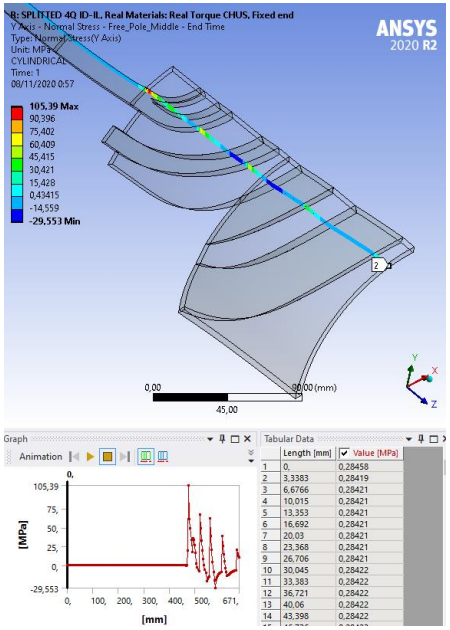


Shorter ID-IL

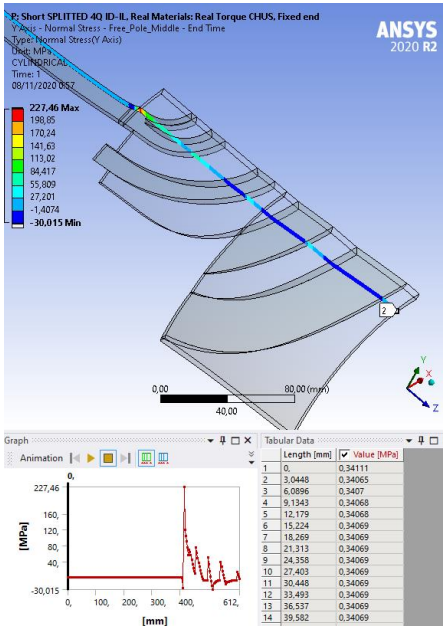


Path along Free pole: Azimuthal stress

Present ID-IL

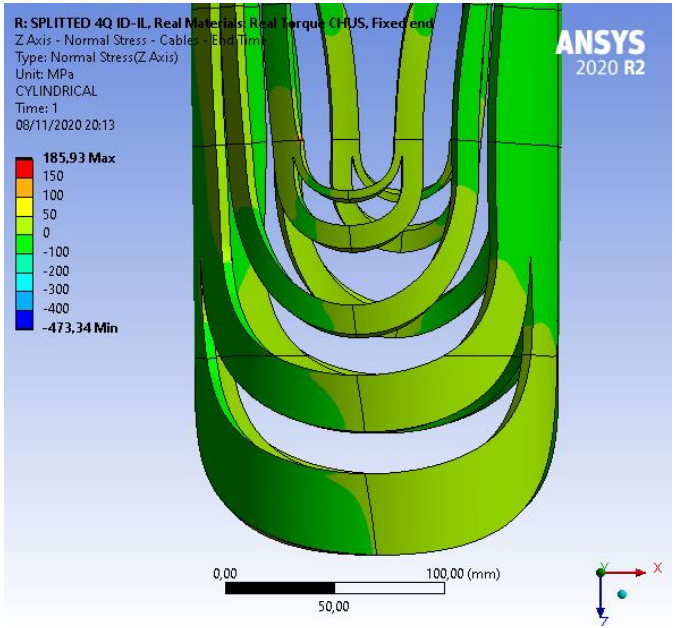


Shorter ID-IL



Cables: Z stress

Present ID-IL



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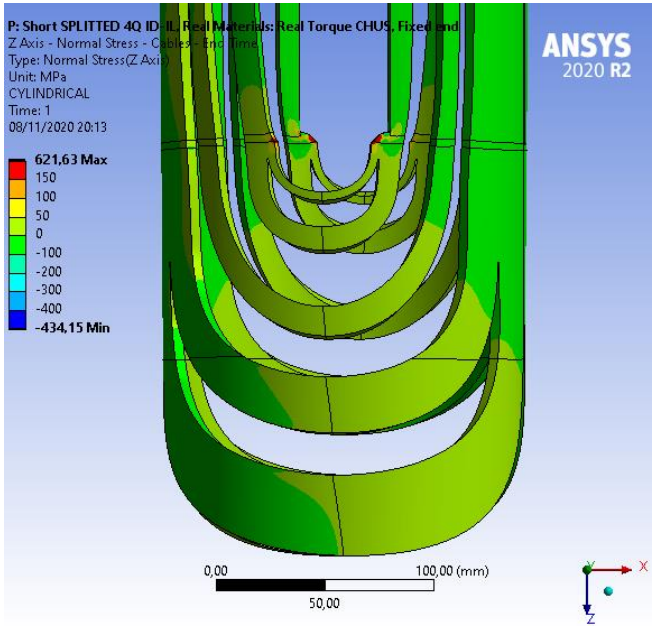
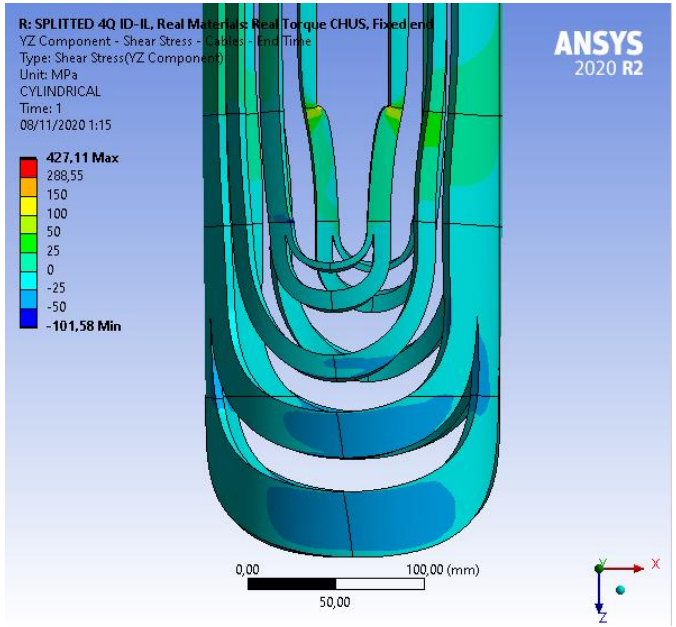
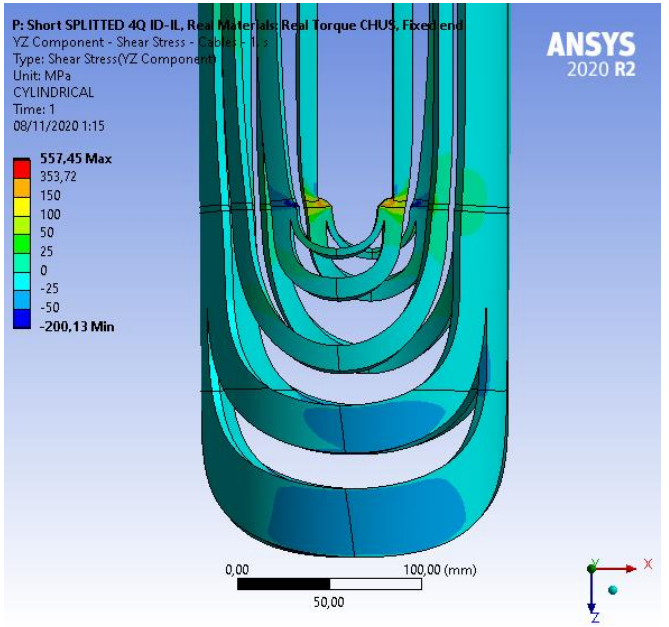


Cables: YZ Shear stress

Present ID-IL

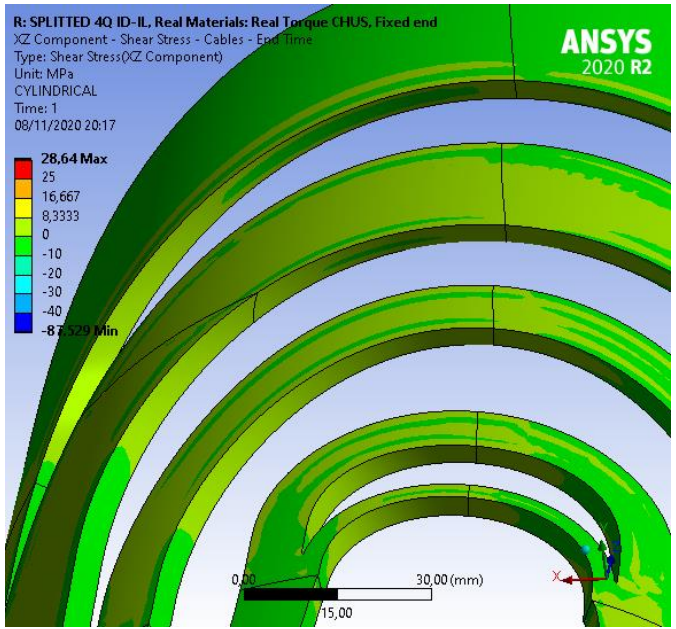


Shorter ID-IL



Cables: XZ Shear strees

Present ID-IL



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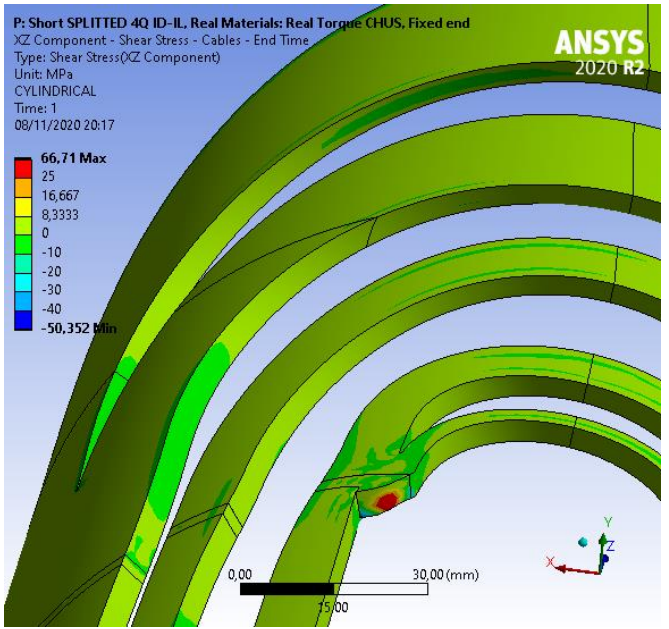
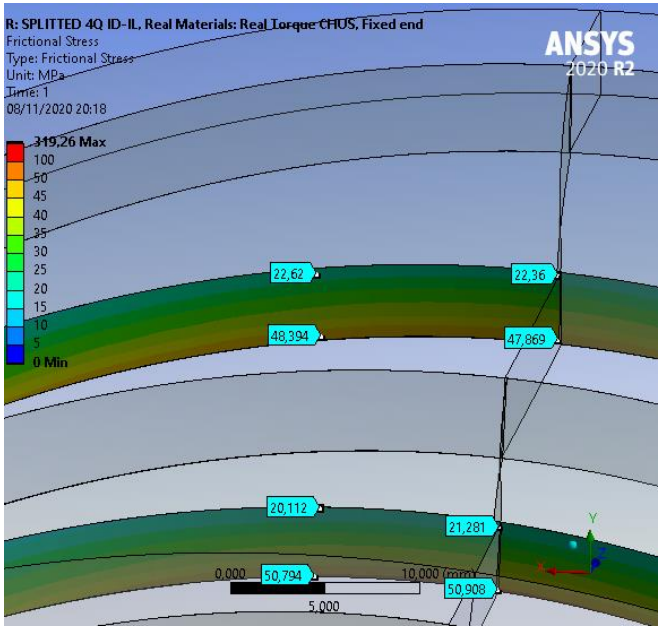


Contacts: Frictional Stress (Gradient)

Present ID-IL



Shorter ID-IL