U.S. MAGNET DEVELOPMENT PROGRAM

Nb_3Sn CCT Updates and Next Steps

USMDP Bi-Weekly Meeting - 07/16/2025

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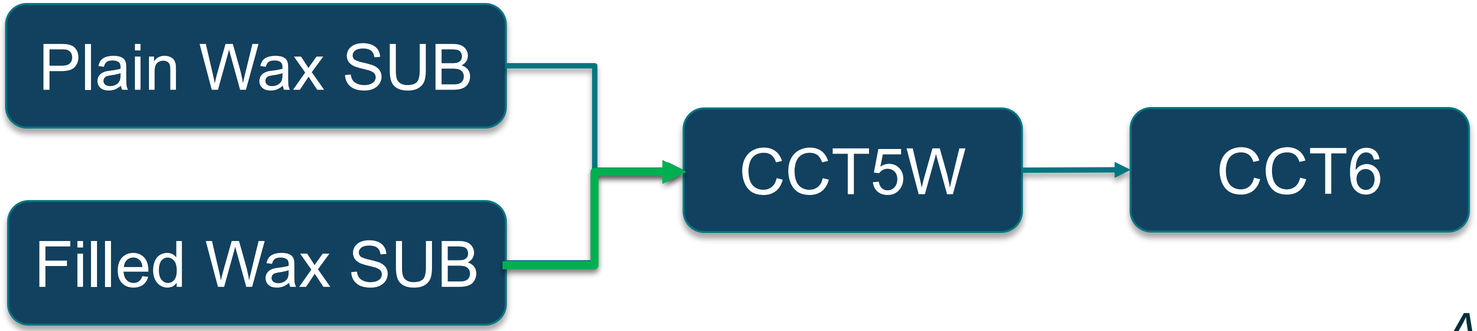
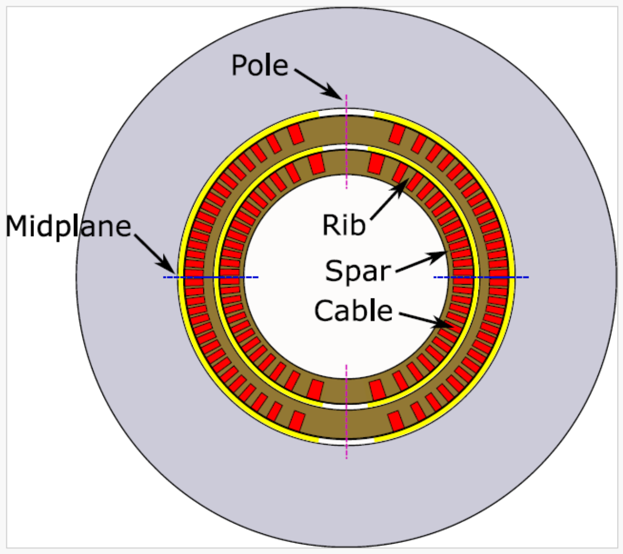
Outline

- General Updates
  - CCT5-W updates
  - CCT subscale updates and plans
  - CCT6 updates and plans

CCT5W Motivation

- Under conditions where there is no bonding to the ribs in CCT, the edge of the cable sees higher normal stress
- CCT5W, wax impregnated CCT5 @10T 90 mm bore (CCT5-W), has been fabricated as a stepping-stone towards CCT6
  - Average radial stress of CCT5 at 10 T is representative of CCT6 at ~12 T. Subscale stresses are significantly lower.
  - If CCT5-W is successful, can consider to impregnate CCT6 with filled wax
- CCT5W follows same general approach as for CCT5, with only following modifications:
  - Coil impregnation with filled wax
  - Larger shim angle between layers





Stress on Turn from Lorentz Force

			2D FE - Magn	
Magnet	**Current**	**Field**	**srr_em**	**stt_em**
	kA	T	MPa	MPa
Subscale	9.5	5.3	15	10
CCT5	17.8	**10.0**	**71**	3
CCT6	10.67	**12**	**85**	5
CCT6	14.22	16	152	9

Analysis performed by: G. Vallone and M. Juchno

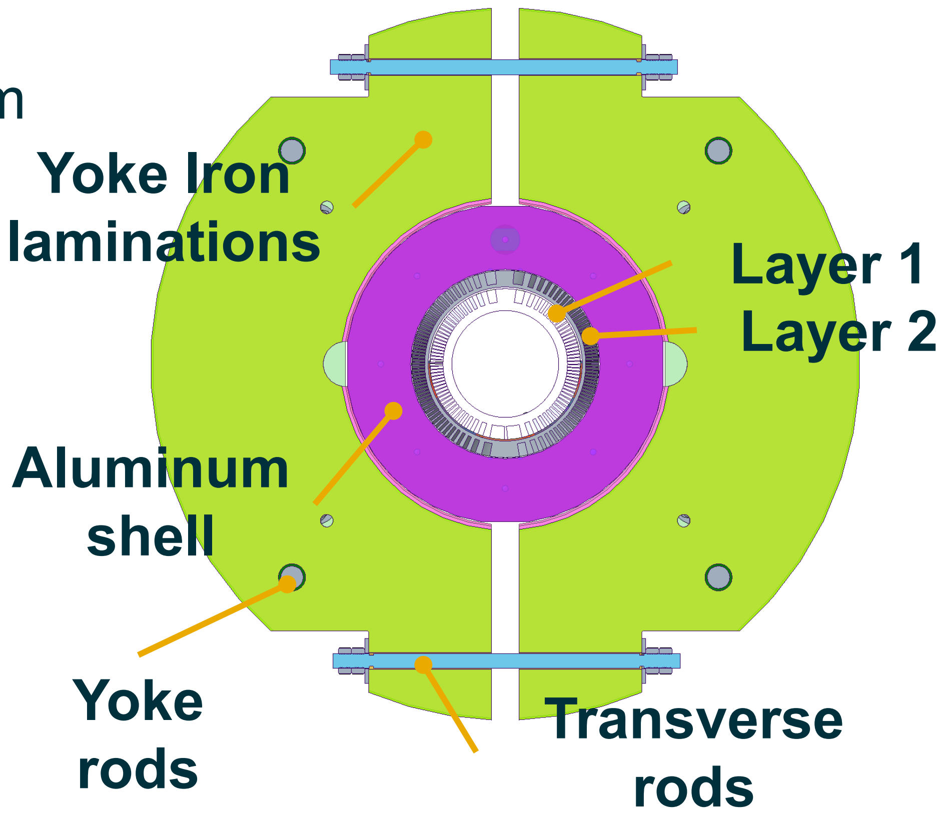
CCT5W Design Overview and Parameters

- Magnet Parameters
  - 2-Layer CCT
  - 21 strand cable (MQXF strand)
  - Bore diameter: 90 mm
  - Aluminum Shell
  - External yoke
  - Magnet length: 1 m

Magnet main dimensions

Parameter	Unit	CCT5 Value
Layer 1, inner diameter	mm	90
Layer 1, outer diameter	mm	126.8
Layer 1, spar thickness	mm	7.4
Layer 2, inner diameter	mm	129.8
Layer 2, outer diameter	mm	157.6
Layer 2, spar thickness	mm	2.9
Shell, inner diameter	mm	160.6
Shell, outer diameter	mm	270
Magnet length	mm	1000

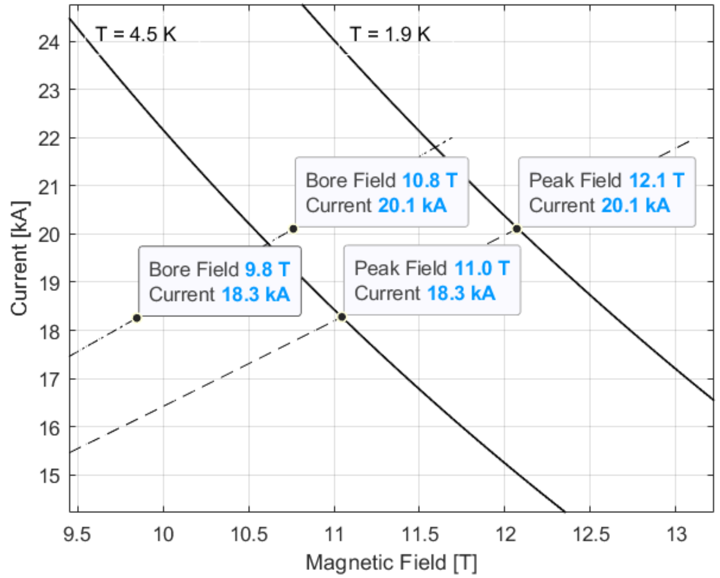
CCT5W Layout



Magnet cable parameters

Parameter	Unit	CCT5 Value
Conductor Type	-	RRP 108/127
Strand Diameter	mm	0.85
Cu:non-Cu ratio	-	1.2
Number of Strands	-	21
Cable Width	mm	10.1
Cable Thickness	mm	1.5
Reaction Gap	mm	1.65

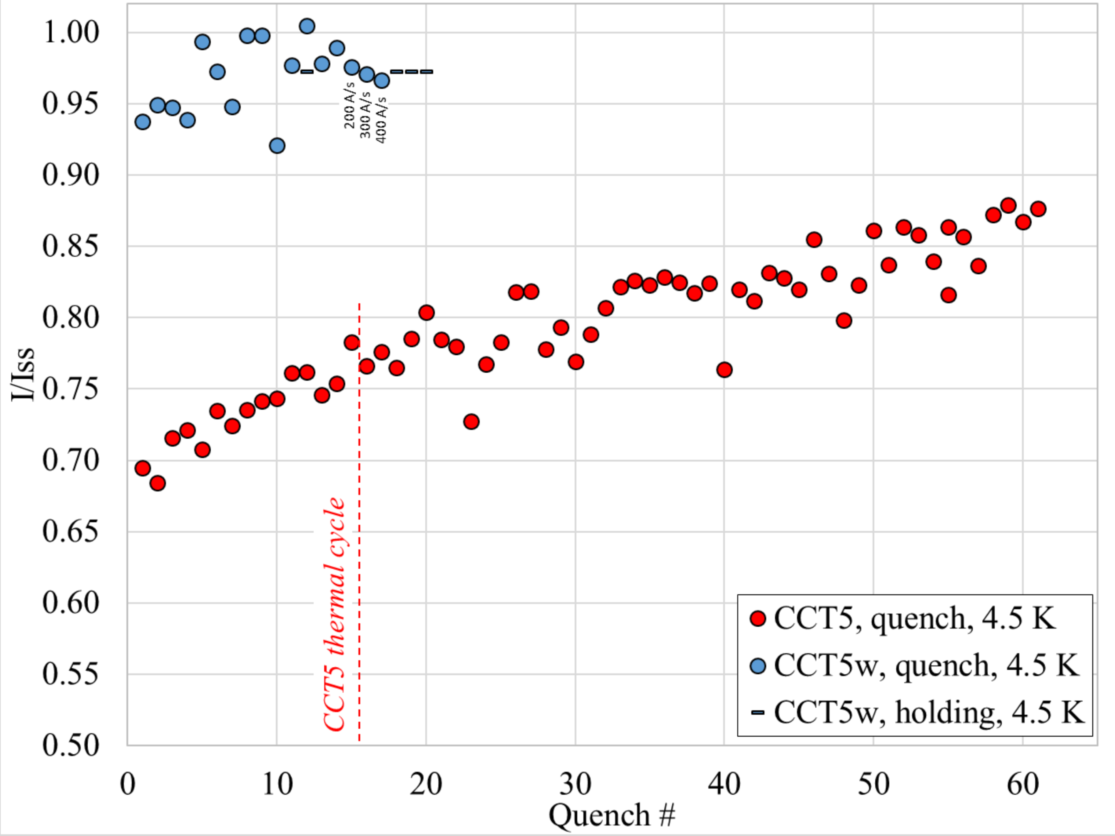
Load Line



CCT5W Results Summary and Next Steps

- Initial testing at Fermilab at 4.5 K has been completed (see talk from Stoyan)
- Magnet training starts at ~93% of the short sample limit and multiple cycles show stable operation of the magnet at ~97% of the SSL
- Testing will resume at 1.9 K

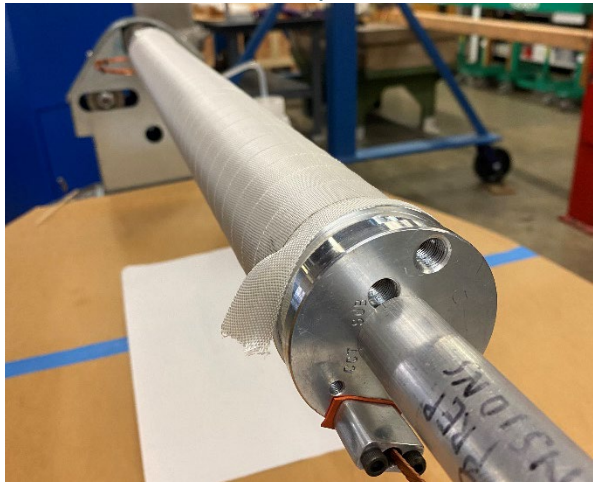
CCT5 / CCT5W Training



CCT Subscale Current Activities

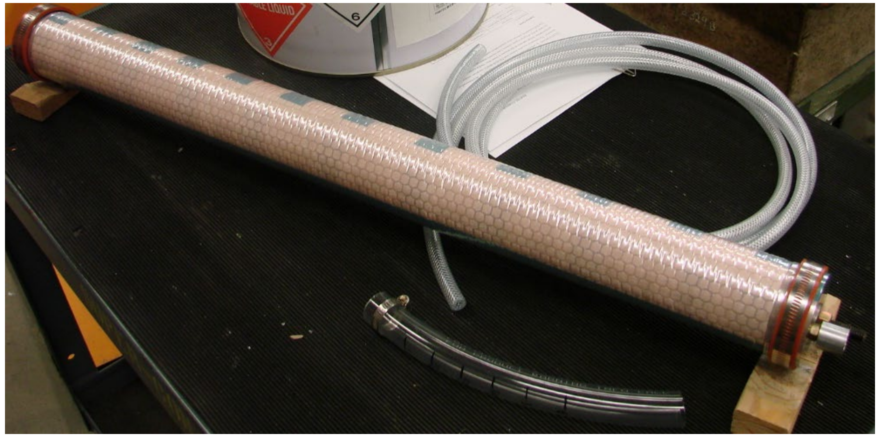
- Two subscales planned for near future
  - Telene impregnated coils (part of US-Japan program)
  - Filled epoxy impregnated coils
- Inner layer coil for Telene impregnation is reacted and being prepared for impregnation
- Outer layer mandrel is available and ready for winding and reaction (to be completed over next month)
- Test coils is at Fermilab for impregnation test

Inner Layer Coil



Outer Layer Mandrel

Test Mandrel



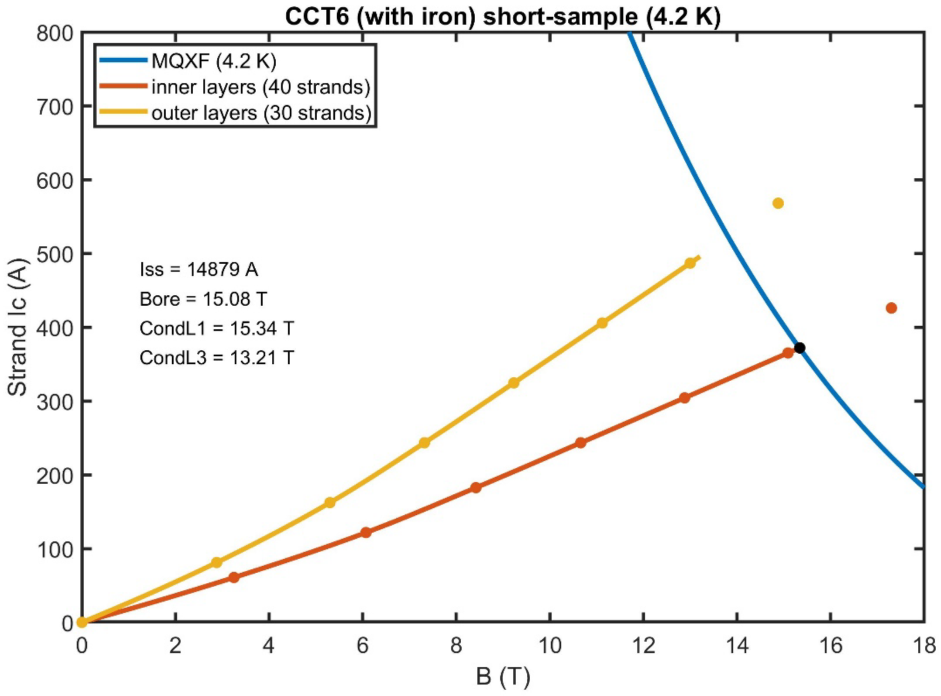
Filled Epoxy Preliminary Tests

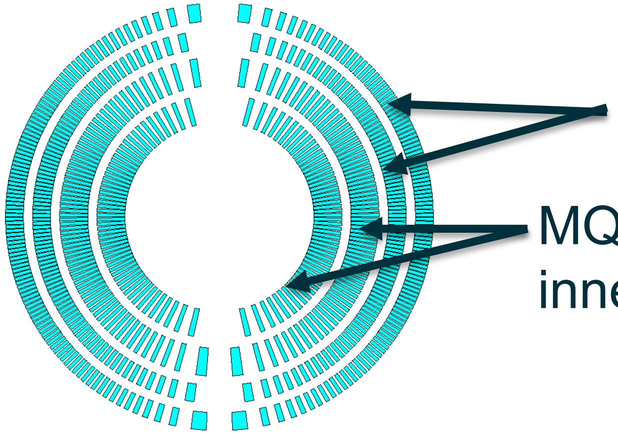
Effort led by J.L. Rudeiros Fernandez and A. Saravanan

- Motivation
  - BOX experiments at PSI / Twente showed improved training performance for filled resins (e.g. CTD-101K with Al2O3 filler)
  - BOX experiments with Stycast 2850 show almost no training
- We found impregnation with Stycast 2850 FT difficult in previous tests which was likely dominate by large particle size
- Developing recipe for mixing the small particles (~500 nm) used for filled wax in epoxies
  - Following approach developed by A. Brem at PSI for CTD-101K using SolPlus dispersant
  - Exploring effect of dispersant on viscosity of mixture
  - Will explore use of various resins
- Samples are being prepared for pull-out tests at room temperature and 3-point bending specimens (most promising samples to be tested later in energy deposition experiment)

CCT6 Design was Updated Based on Feedback from Test Coil Machining, Widing, and Reaction

- Design was updated with MQXF cable for inner layers and new cable for outer layers (as presented at USMDP collaboration meeting)
- Fabrication of inner layer coil is in progress

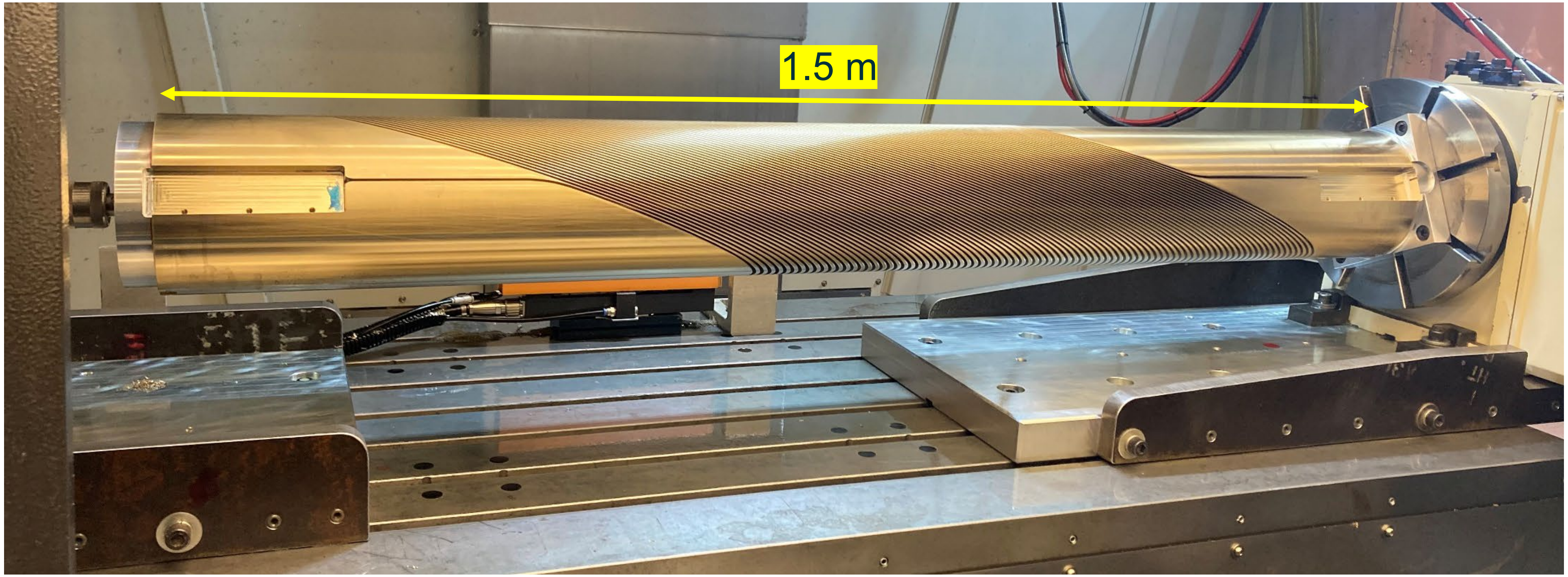


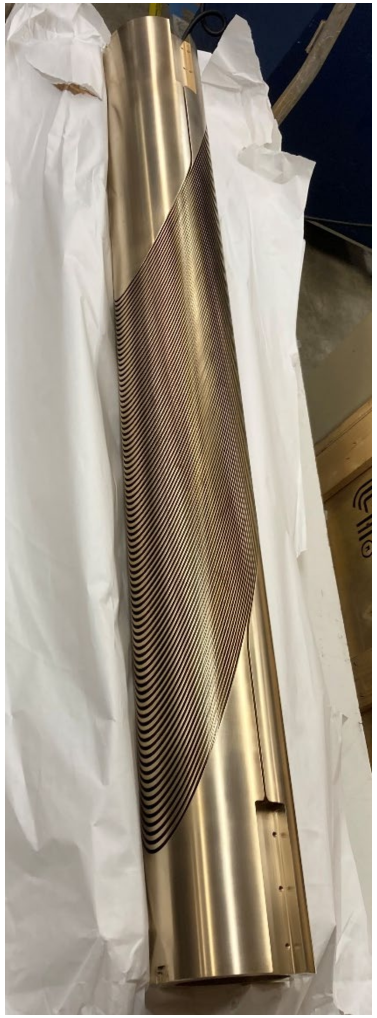


Physical length	L (1% of B1)	Bbore @ 4.2 K SS	Bcond @ 4.2 K SS	Bbore @ 1.9 K SS	Bcond @ 1.9 K SS
1.5 m	194 mm	15.1	15.3	16.3	16.6

Layer 1 Mandrel Machining Complete

- Layer 1 mandrel machining was completed at LBL main machine shop
- Total fabrication duration was ~2 months (3 months total but ~ 1 month was lost due to machine breakdown)

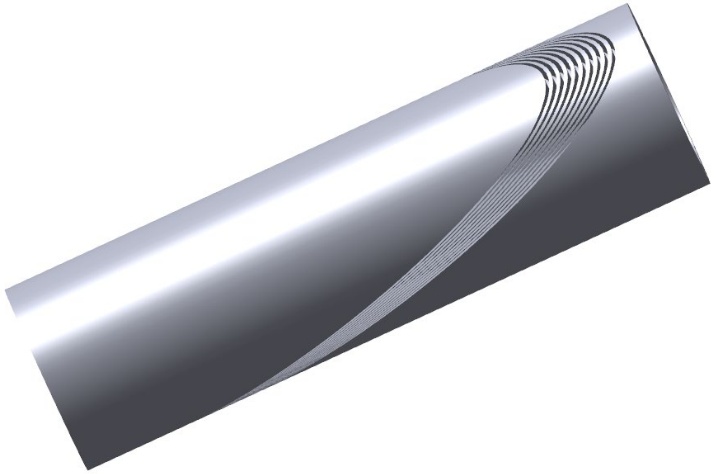




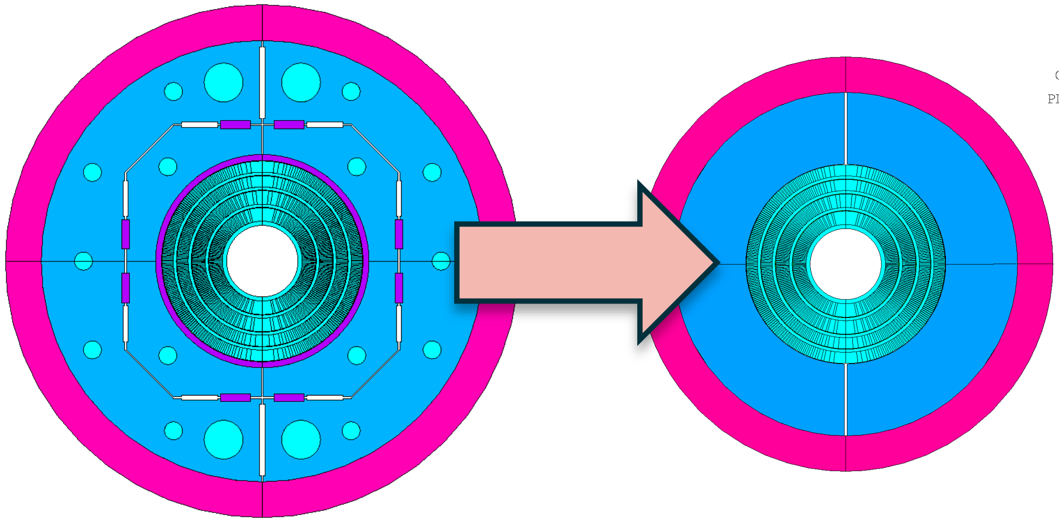
Next Steps for Mandrel Machining

- 10-turn layer 2 mandrel design is complete and tube is ready for groove machining
  - Contains 2 different types of grooves (1 set is same as for L1 and second set has slightly larger gap)
  - Will perform winding and reaction test to select groove geometry for L2 mandrel
- Will use larger diameter cutting tool with goal to improve machining efficiency
- Plan to test splicing process on 10-turn test mandrel before splicing is performed on L1 coil

10-turn Layer 2 Mandrel



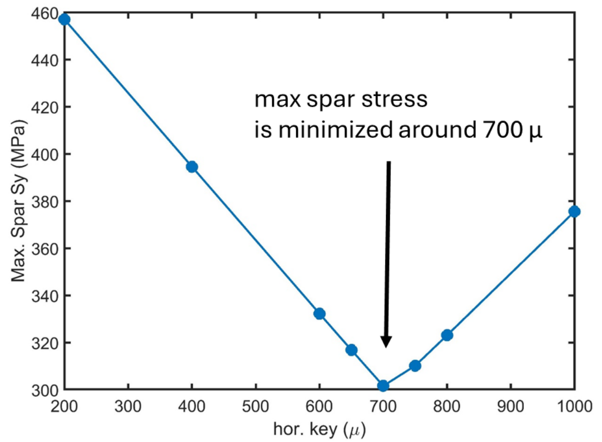
Exploring Design of a Simplified Structure using “smart-shim” Assembly Techniques



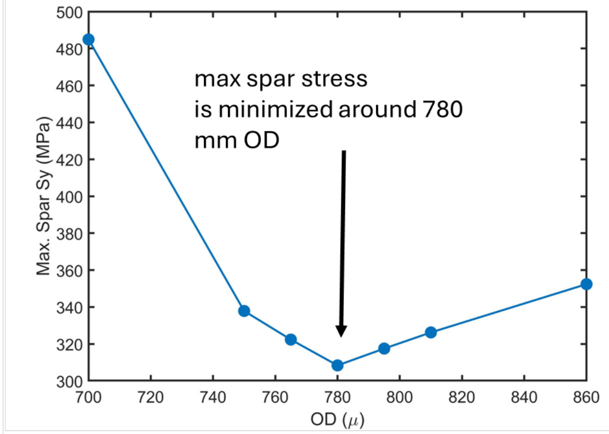
Assembly procedure with the simplified structure
- stretch shell using bladders/keys in vertical split at pole
- inflate Kapton bags between layer 4 and yoke and let cure

Room temperature preload is now adjusted during the yoke into shell assembly process (we give up some flexibility for simplicity and a stiffer structure)

Optimized key and bladder structure (860 mm OD)



Optimized simplified structure (780 mm OD)



Concept and calculations by L. Brouwer

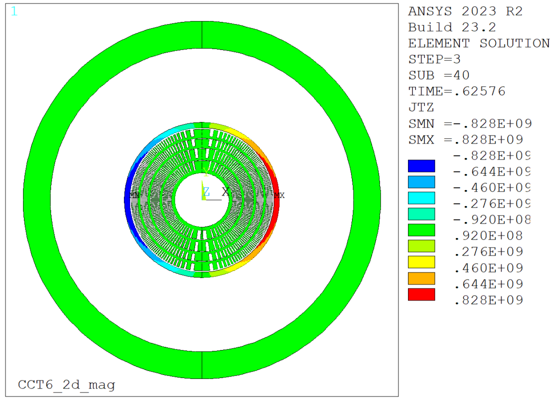
Quench protection studies needed to define outer layer cable parameters

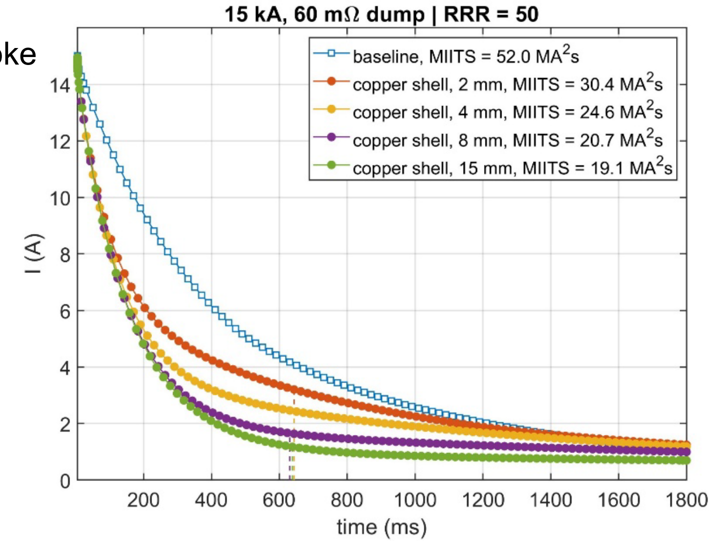
Preliminary studies have been performed to explore the addition of low resistivity material for energy transfer (through eddy currents)

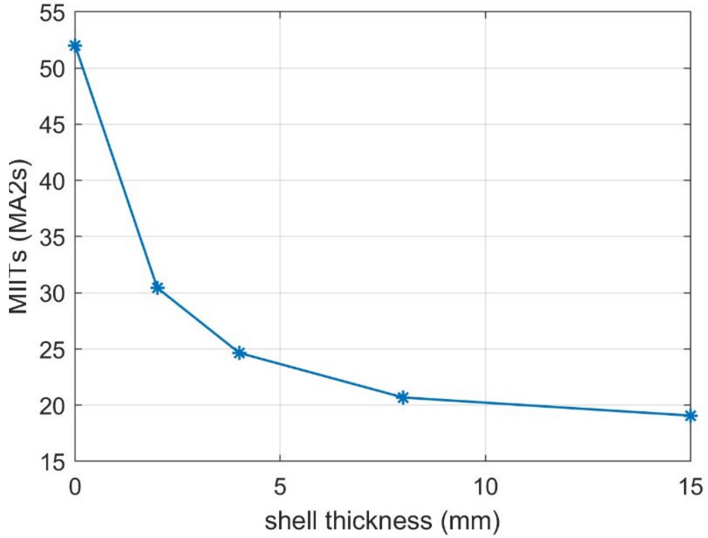
Circuit coupled modeling in ANSYS

Analysis by Yufan Yan

Cu shell added between coil and yoke

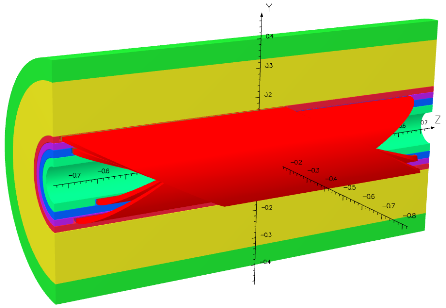


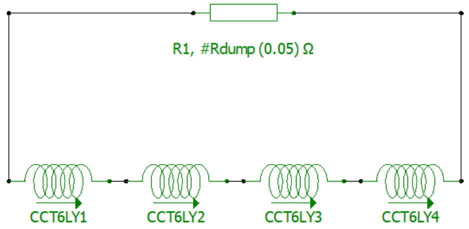


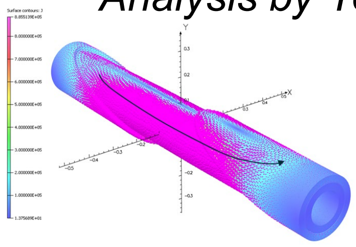


Opera3D quench module for including propagation

Analysis by Ye Yang







CCT6 Next Steps

- Winding of Layer 1
- Complete 10-turn layer 2 test (machining, winding, reaction, splicing)
- Complete fabrication of layers 1 and 2
- Complete quench protection study to finalize outer layer grading
- Further optimization of 3D mechanical design leading to choice of final structure (ongoing)