U.S. MAGNET DEVELOPMENT PROGRAM

Update on Nb_3Sn Dipole CCT Magnets

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Outline

- Review of Subscale program tests to date
- Recent test results and upcoming tests
  - Disassembly / Reassembly test of Sub2
  - Progress towards testing of Sub5 (wax) (*Covered by Jose Luis*)
- Quench antenna results update (*Covered by Reed*)
- CCT6 modeling and prototyping updates (*Covered by Lucas*)

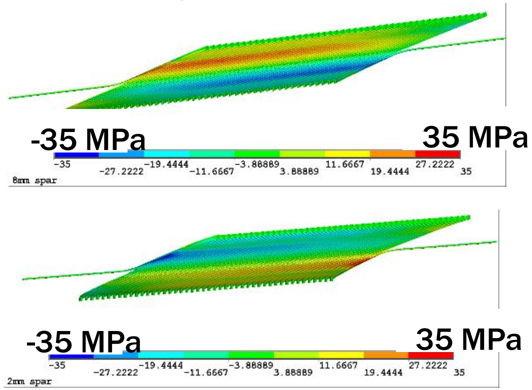
Three subscale magnets have been fabricated and tested

- First two magnets have inner layers with thin (Sub 2 / baseline) and thick spars (Sub 3)
  - Thin spar → reduced interface shear stress and increased normal stress due to bending
  - Thick spar → increased interface shear stress and reduced normal stress due to bending
- Third magnet used new non-epoxy high toughness resin from CTD-701x (*SBIR collaboration led by T. Shen at LBNL*)
- Fourth magnet with wax impregnated inner layer and is currently being assembled

Sxy (radial-azimuthal)

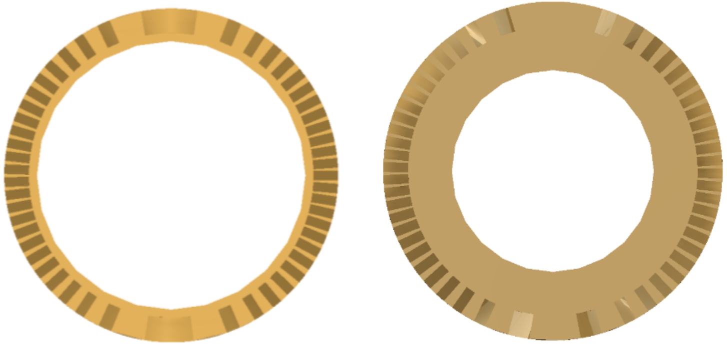
8 mm spar

2 mm spar



Thin Spar (Baseline)

Thick Spar



A Total of Seven Magnet Tests Have Been Performed Until Now

CCT Sub2

- Initial Test
- Test after thermal cycle
- Test after disassembly and reassembly
  - Demonstrated that the magnet can be disassembled without damaging the coils
  - Outer layers can be re-used for future tests

CCT Sub3

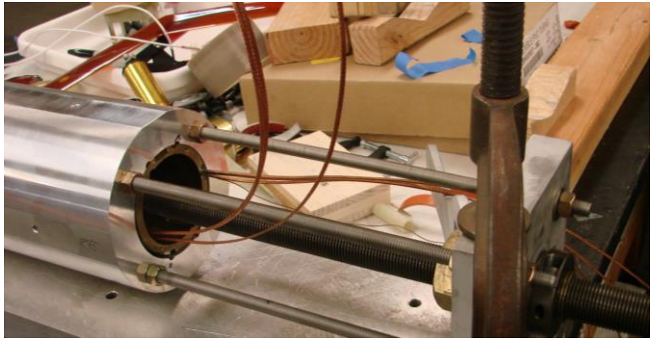
- Initial Test
- Test after thermal cycle

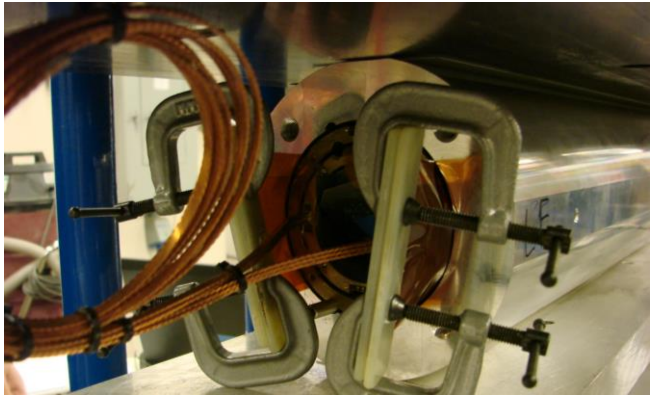
CCT Sub4

- Initial Test
- Test after thermal cycle*

** magnet was limited at or near the internal splice*

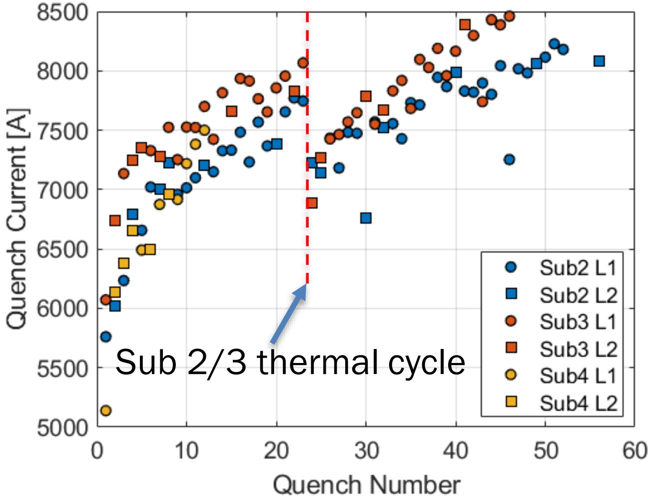
Sub2 Disassembly / Reassembly

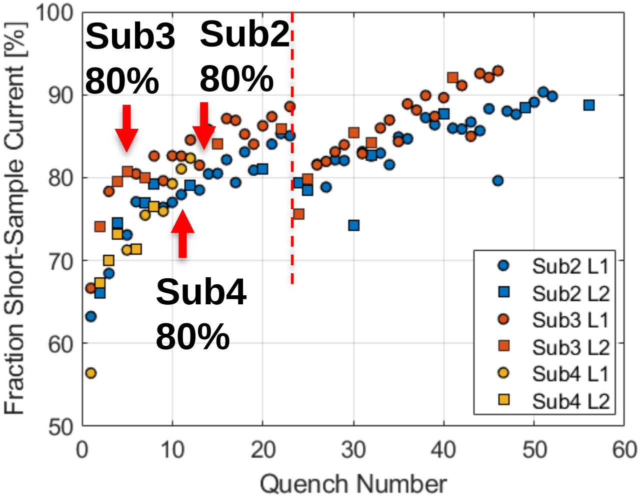




CCT Subscale 2, 3, 4 Training Summary

- Comparison between Sub2 and sub3
  - Sub3 (6100 A, 67% of SSL) starts at slightly higher current quench when compared to Sub2 (5800 A, 64% of SSL)
  - Sub3 (8000 A, 88% of SSL) reaches slightly higher current after a similar number of quenches compared to Sub2 (7700 A, 85% of SSL)
  - Sub3 (8400 A, 92% of SSL) reaches higher final current after thermal cycle compared to Sub2 (8200 A, 90% of SSL)
- Comparison between Sub2 and Sub4
  - Sub4 starts lower than Sub2 but seems to have a higher training rate (Test stopped early – later found limiting area in or near coil splice)



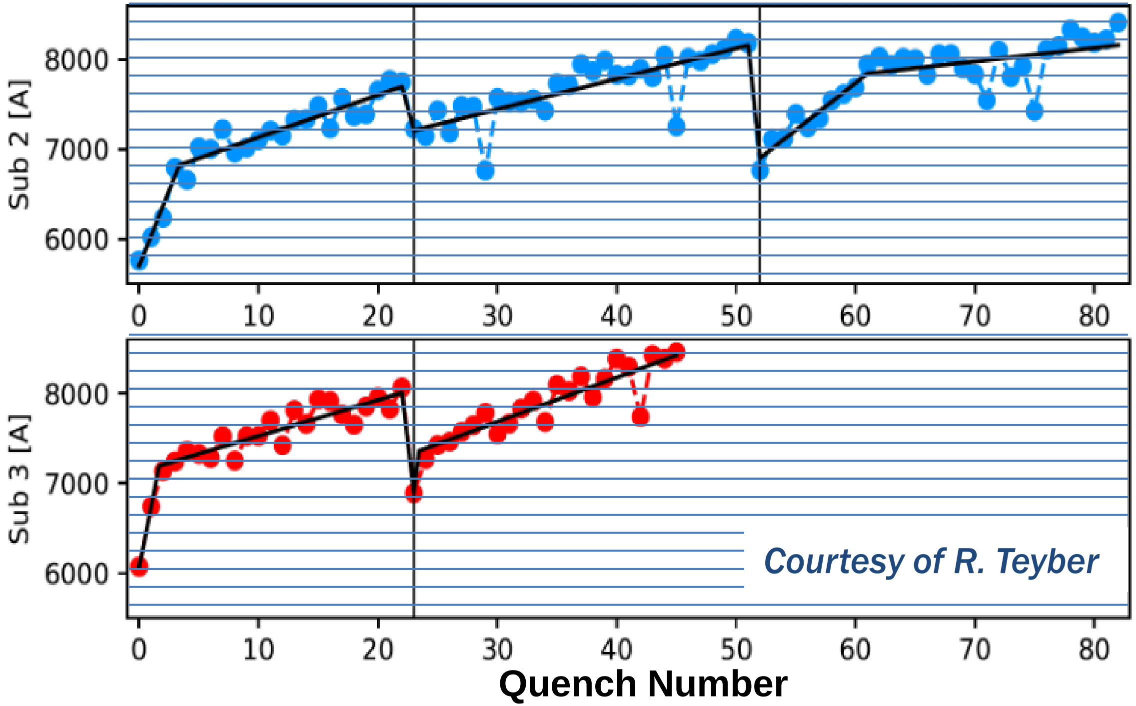


Approximately 75% of quenches in inner layer

Sub2 – baseline
Sub3 – thick spar
Sub4 – CTD 701x resin

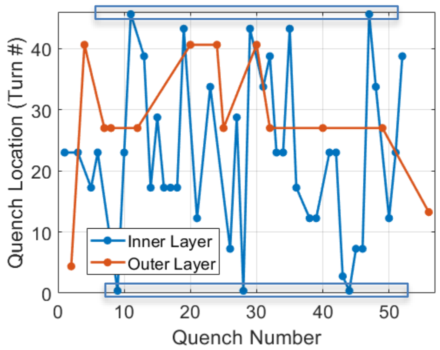
Thermal Cycles: Quench Current and Training Rate

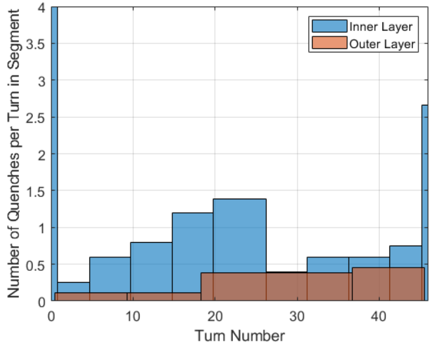
- Both magnets show fast then slow training behavior (knee)
- Knee behavior is mostly gone after thermal cycle
- Both magnets show some detraining after thermal cycles
- Long knee with reduced training rate after Sub2 disassembly / reassembly



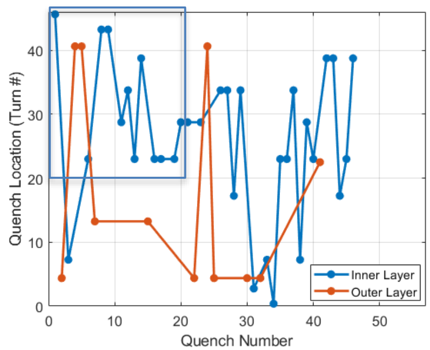
Quench Segment Distribution

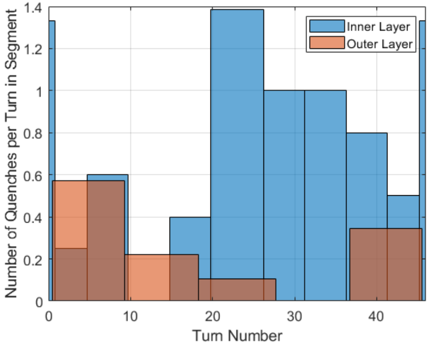
Sub 2



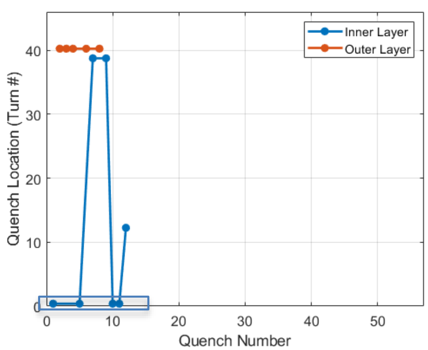


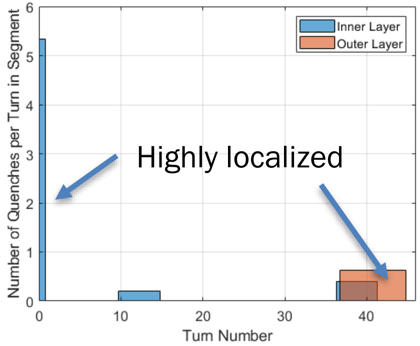
Sub 3

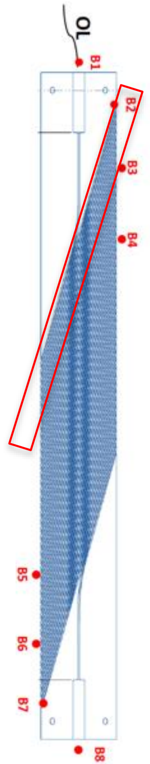




Sub 4







Conclusions

Subscale Test Observations

- Thick spar inner mandrel leads to somewhat reduced training
  - Training is not fully driven by shear stress in the conductor groove
  - Advanced debonding models are being pursued to better understand behavior
- Thin spar coils have disproportionately more quenches near first and last turn
- Fast training segment is present after reassembly (minimal to no fast training after thermal cycles)

Next Steps

- Subscale
  - Complete CCT SUB5 assembly (wax)
  - Test of ability to impregnate with Stycast (filled resins)
- CCT6
  - Continue testing of winding / reaction with small test mandrel
  - Test of machining process and scale up in LBNL main machine shop (need to machine 1.5 m long mandrels for CCT6)
  - Plan to fabricate inner layer coil in 2023