Tracking the Potential for Damage in Nb_3Sn Superconducting Coils from the Hardness of Surrounding Copper

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Funding Grants: CERN PO CA7854000, G.S. Boebinger (NSF DMR-1644779, State of Florida)

The 11T dipole magnet needed for the high luminosity upgrade of CERN's Large Hadron Collider (LHC) is a key milestone for future superconducting Nb_3Sn magnets. The MagLab's Applied Superconductivity Center has been a driver of superconducting wire research for High Energy Physics programs funded by the U.S. Department of Energy for decades. This team recently determined the source of failure in a prototype 11 T low-temperature superconducting (LTS) accelerator magnet assembled at CERN through a collaboration that includes an undergraduate funded by the NSF's Research Experiences for Undergraduates program.

Metallographic autopsies of both degraded and undamaged 11T dipole magnet sections found Nb_3Sn filament cracks in the degraded sections (Fig 1) but not in undamaged sections. Locations of high fracture density matched those predicted for excessive stress during a critical step in the magnet assembly. The strain history in the surrounding Cu was estimated by micro-hardness (Fig 2) and compared with test samples that had been strained under known uniaxial stresses. The magnet values correlated well with the control samples stressed under known loads.

Results indicate that copper hardening in Nb3Sn conductor is a tell-tale that a magnet has been pushed beyond its stress limit. The experience gained will guide future design and models of large low-temperature superconducting magnets.

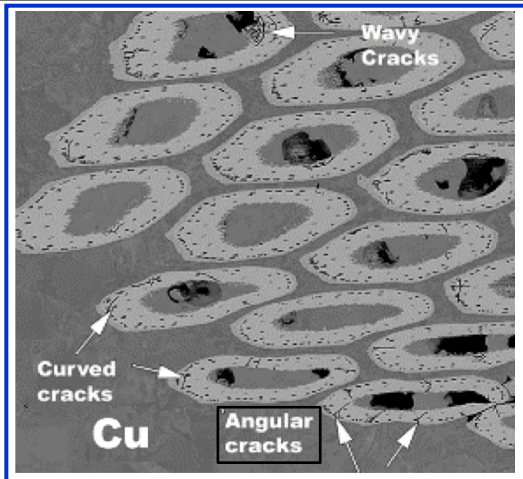

Fig 1: Electron microscope image showing cracks in a conductor that was extracted from a damaged Nb_3Sn coil that was part of a prototype 11T accelerator dipole magnet built at CERN. The cracks resulted from overstresses experienced during assembly of the model coil.

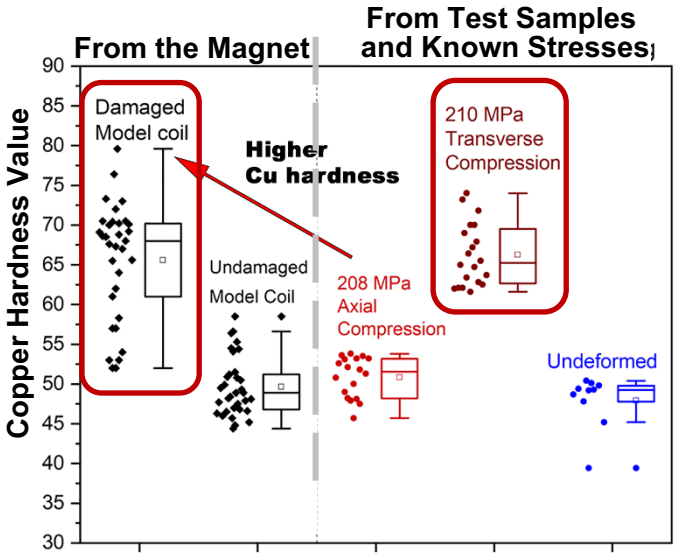

Fig. 2: Comparison of the Cu hardness indicates stresses of over 210 MPa were reached locally in the Nb_3Sn conductor in the damaged magnet model coil (compare data in two red boxes), resulting in damage to the model coil in the form of Nb_3Sn filament breakage. A hardness value over 75 in nearby Cu leads to damage in Nb_3Sn magnets.

Facilities: Applied Superconductivity Center

Citation: Balachandran, S.; Cooper, J.; Lee, P.; Van Oss, O.; Bottura, L.; Savary, F.; Scheuerlein, C.; Wolf, F.; Devred, A., *Metallographic analysis of 11T dipole coils for High Luminosity-Large Hadron Collider (HL-LHC),* **Superconductor Science and Technology 34**, 025001 (2021) doi.org/10.1088/1361-6668/abc56a