05.12.23 – RDL4 Mtg

Modelization of Impregnated Nb_3Sn Cable Composite at PSI

B. Auchmann (PSI/CERN), D. M. Araujo, A. Brem, M. Daly, A. Milanese (CERN)
X. Kong, P. Studer, T. Tervoort (ETHZ/D-MAT/SMG)

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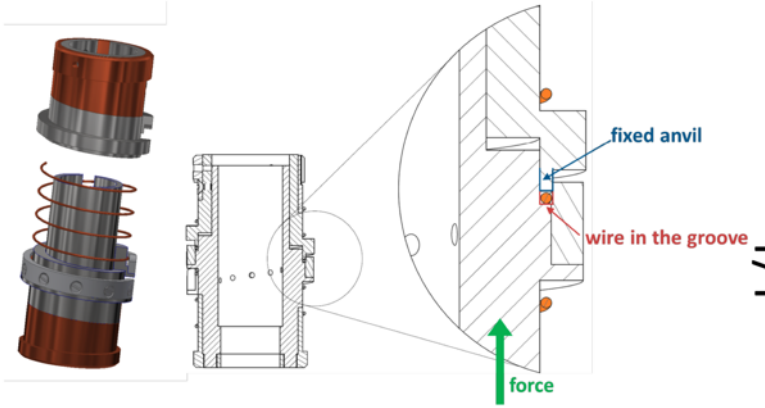
CHART / SMACC / Materials

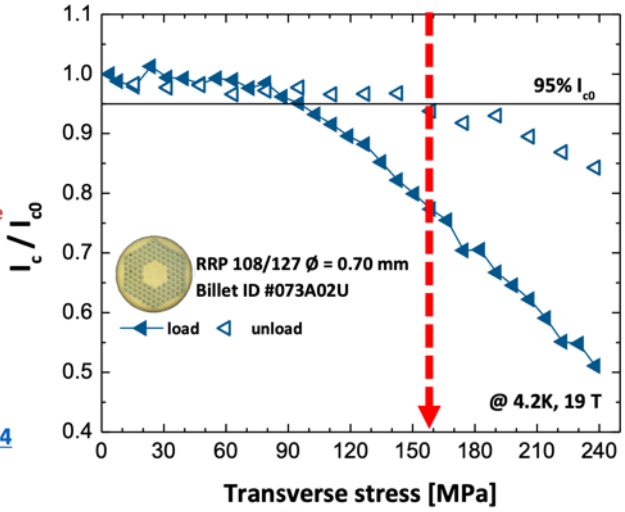
- CHART is a research network. LTS ASC competences are distributed
  - Conductor, Cable: UniGE, CERN
  - Insulation materials (resins, 10-stack characterization): ETHZ SMG, PSI
  - Powered samples: PSI, UTwente
  - Magnet design and construction: PSI
- PSI is working on stress-managed solutions → special requirements for coil composite:
  - Training in CCTs and possible all SM solutions scales with length of magnet.
  - Minimal-training impregnation material required.
  - No RT preload → relatively soft materials are eligible.
- The BOX program has identified candidates:
  - Paraffin wax
  - Filled paraffin wax
  - Filled epoxy
- No 10-stack data or Walther-spring measurements exists with these materials.

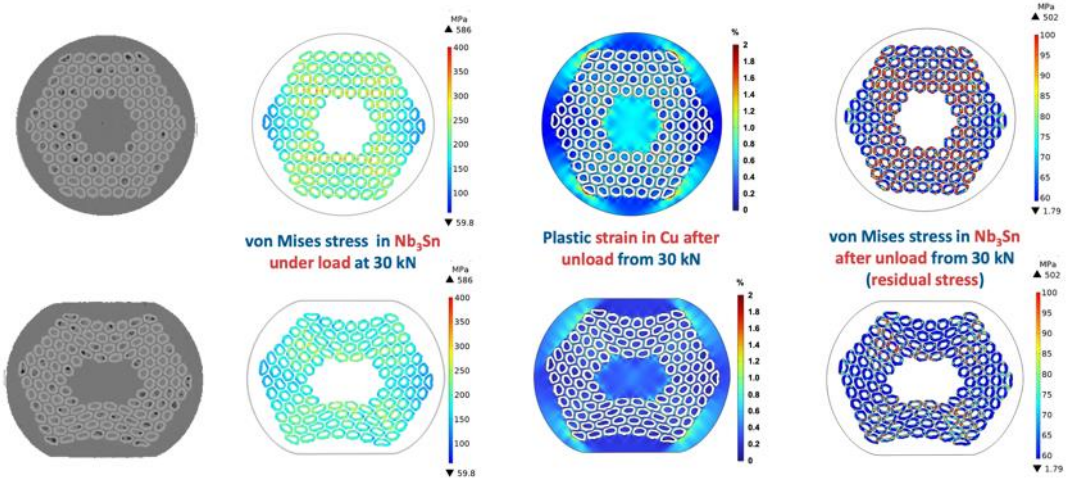
Multi-scale 1/5 WireChar

- UniGE: WASP measurement and simulations.



The WASP concept was adapted to transverse loads by
B. Seeber et al., IEEE TAS 17 (2007) 2643, DOI: 10.1109/TASC.2007.897934



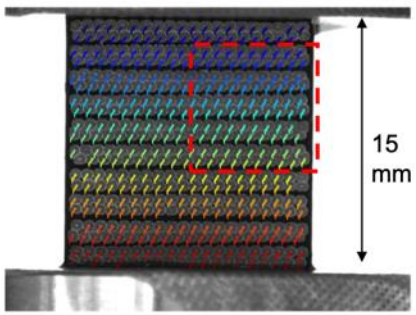


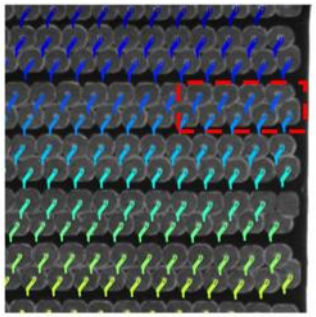
[C. Senatore, M. Bonura, et al., CHART annual meeting, indico link, Oct. 2023.]

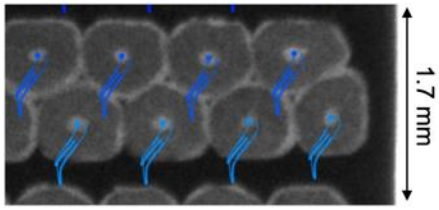
Multi-scale 2/5 MagComp

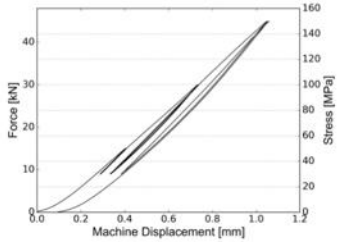
- ETHZ: 10-stack measurements with image analysis (particle-tracking method).
  - Epoxy vs. paraffin, vs. filled epoxy and paraffin.

Trajectory of each strand-core

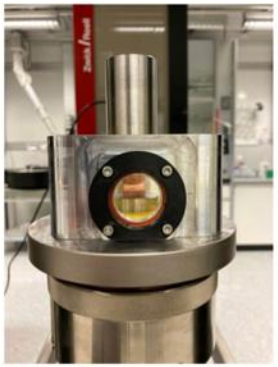


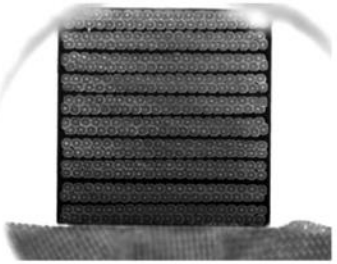






- Most (380/400) strands are tracked during the loading
- There is a horizontal rigid body motion





Still developing:
- Liquid boiling affects image capture

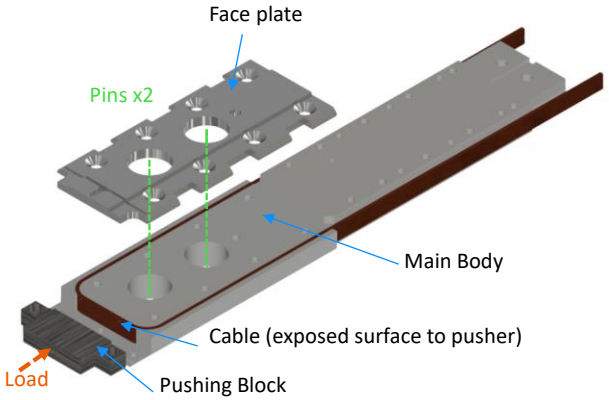
[X. Kong, T. Tervoort, et al., CHART annual meeting, indico link, Oct. 2023.]

- Extraction of homogenized material description for ANSYS (or other) pending.

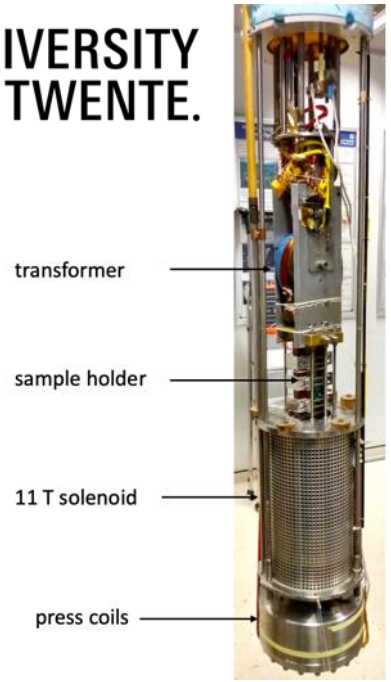
Multi-scale 3/5 MagDev

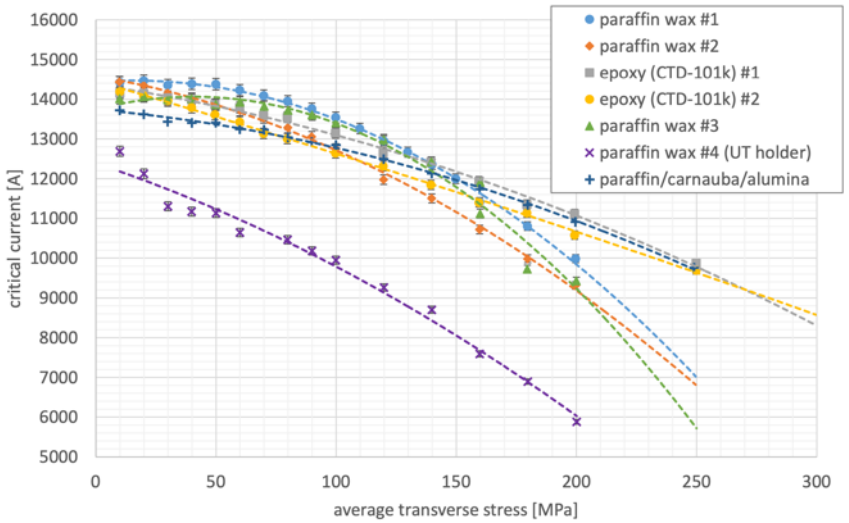
- PSI/UTwente: transverse pressure characterization of Rutherford cable in background field.

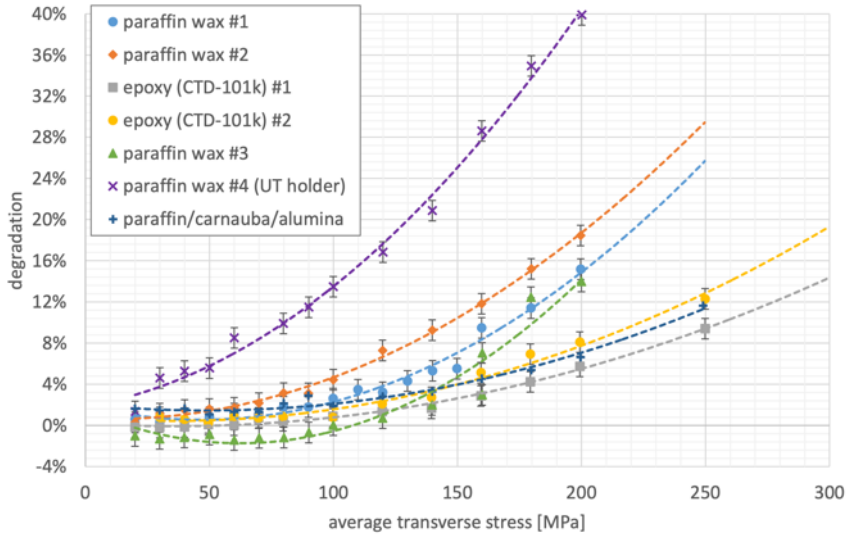
[M. Daly, S. Otten, et al., CHART annual meeting, indico link, Oct. 2023.]



Courtesy M. Daly



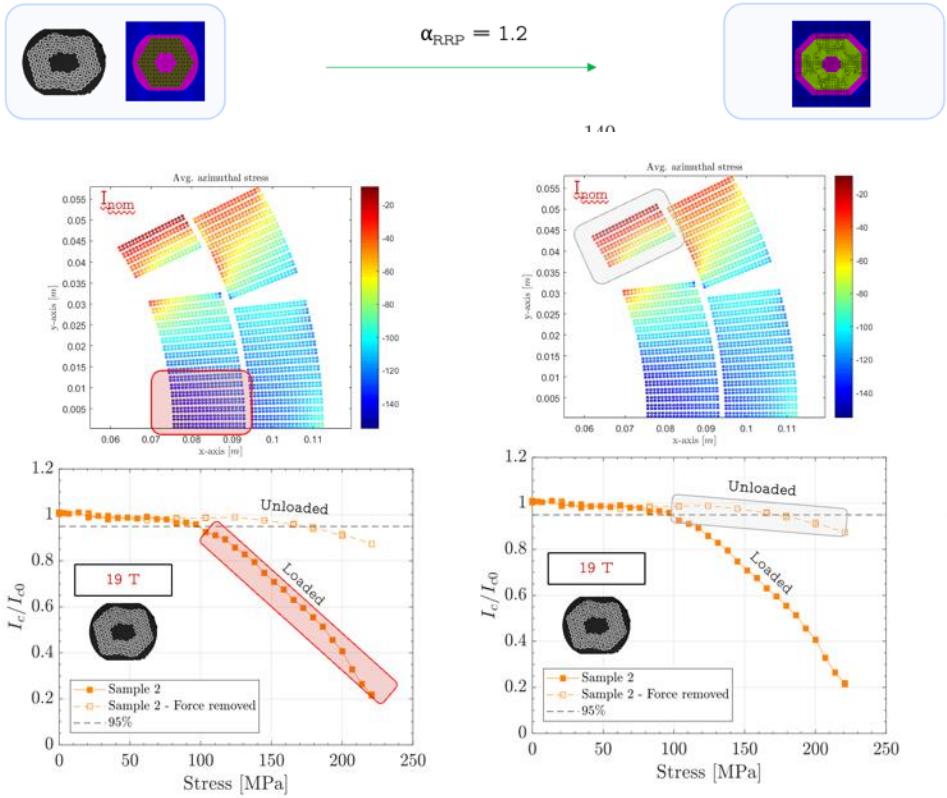




Courtesy S. Otten et al.

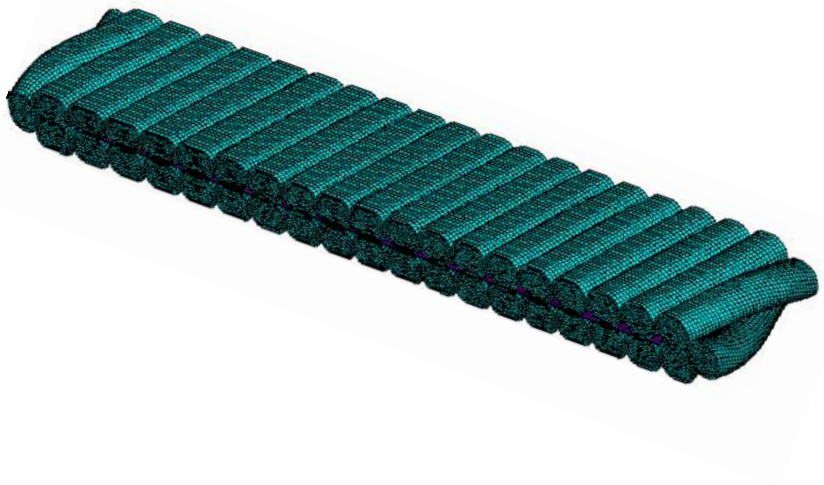
Multi-scale 4/5
2D and 3D Approaches

- Comparison of 10-stack to strand-based 2D models.



[J. Ferradas, TE-MSC Seminar, indico link, June 2023.]

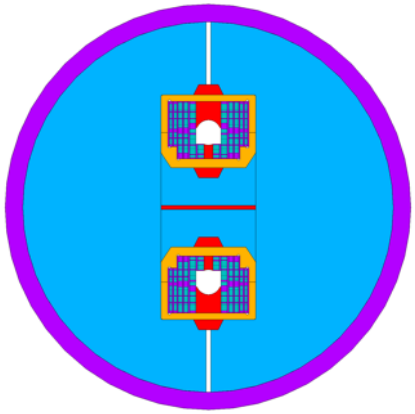
- CEA CoCaSCOPE ANSYS model of 11-T cable for analysis of ETHZ 10-stack measurements.
- Generation of
  - 10-stack model: 3D constitutive law
  - U-shaped UTwente sample: validation of $I_c(\sigma)$

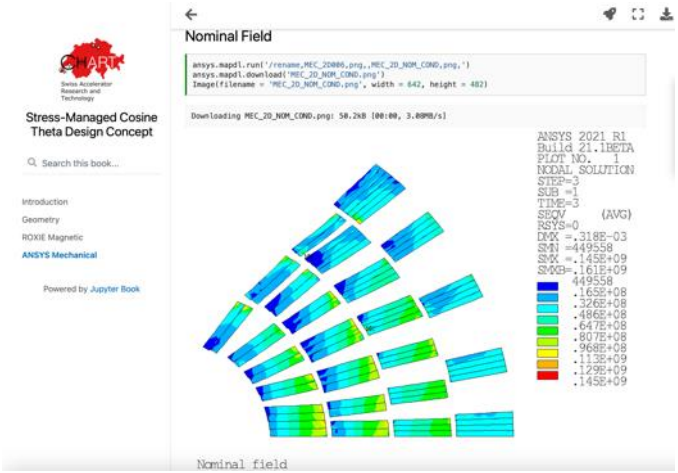


[G. Lenoir et al.]

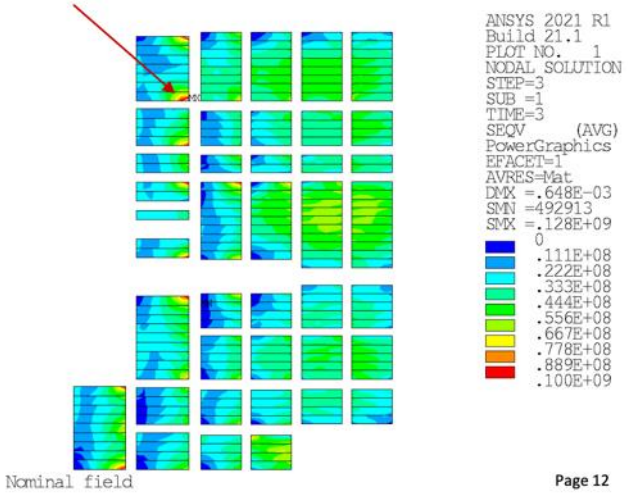
Multi-scale 5/5: Impact on Magnet Design MagNum2

- Include missing mechanical and performance data into conceptual design of SMACC (Stress Managed Common Coil).
- Provide fully *consistent, traceable, and repeatable CDR*, including measurement data, multi-scale FEA model validation, design, and expectations for strain-gauge data, all via Model-Based Systems Engineering (MBSE).
- *Versioned CDR as a living document*.
- PhD at PSI with ETHZ D-ITET-IEF to start in ‘24.





[http://cern.ch/auchmann/chart/magnum http://cern.ch/auchmann/hts4.]



[D. M. Araujo, HFM Annual Mtg, indico link, Oct 2023.]

Future Multi-scale Topics

- Multi-physics multi-scale:
  - Mechanical models, discussed in this meeting,
  - Electromagnetic models (coupling currents, etc),
  - Thermal behavior.
- Up- (homogenization) and down- (return to reference volume) scaling.
- LTS and HTS models.
- ML homogenization experiments.