Measurement of critical current irreversibility limits on ReBCO tapes for mechanical axial tensile strain

G. Anniballi[1], J. Rietberg[1], N. van Dusschoten[1], S. Otten[2], H.H.J. ten Kate[1], R. Lubkemann[2], J. Leferink[2], A. Nijhuis[1,2]

[1] University of Twente, Faculty of Science & Technology, Enschede, The Netherlands.
[2] Foundation SuperACT, Hengelo, The Netherlands.

UNIVERSITY OF TWENTE.

Abstract

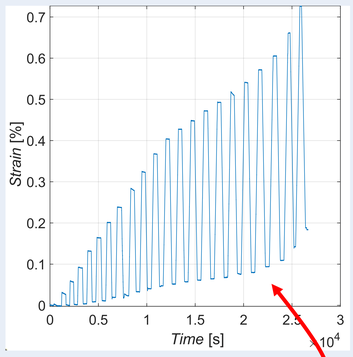
High magnetic fields of up to 20 T in tokamak-type fusion devices, such as in Central Solenoids of European DEMO and the Chinese BEST fusion reactors, require High-Temperature Superconductors (HTS). A promising candidate is ReBCO. The large Lorentz forces occurring under these operating conditions may locally generate high mechanical stresses, which can irreversibly degrade the critical current of the superconductor. For the design of these cables, knowledge is required about the mechanical limits of the tapes. Detailed structural finite element analysis (FEA) based on accurate material electromagnetic and mechanical properties under relevant electromagnetic load levels is needed for reliable and optimal operation. Knowledge of the axial tensile and compressive strain irreversibility limits for the critical current of ReBCO tapes is imperative. For this purpose, the existing TARSIS facility at the University of Twente for axial tensile stress–strain measurements, has been upgraded for testing of ReBCO tapes with critical current measurements at 77 K.

Setup

The new TARSIS facility (Test ARrangement for Strain Influence on Strands)

Main characteristics:

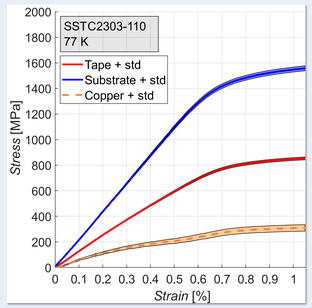
- Sample length: ≧ 20 cm
- Two extensometers in a Nyilas type configuration
- Max current: 400 A
- Operating temperature: ≥ 77 K
- 50 kg Load cell
- Vertical resolution of the TARSIS PVLS: 10 nm
- Current through the sample measured by a zero-flux.

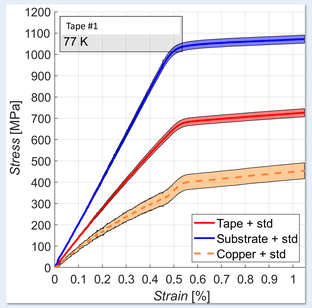


Plastic deformation of the tape induces residual strain at 0 load.

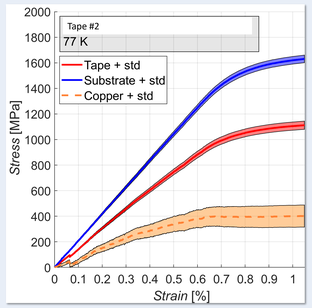
Results

Mechanical properties





Tape	E [GPa]	σ_{ys}* [MPa]
SSTC 2303-110	125.3	841
Tape #1	135.5	694
Tape #2	150.4	1111

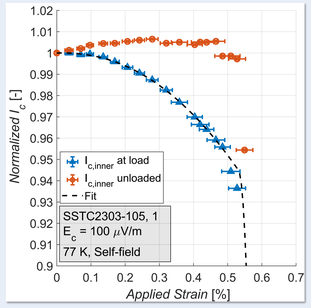


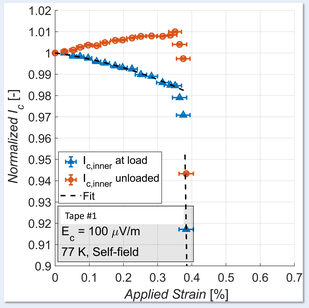
Copper properties not measured but calculated using the rule of mixtures:

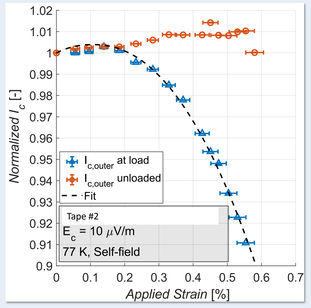
$$\sigma_{Cu} = \frac{\sigma_{tape} - \sigma_{substrate} * w_{substrate}}{w_{Cu}}$$

* In case of bilinear material properties

Electromechanical properties







Tape	Ic [A]	ϵ_{irr} [%]	$\epsilon_{yield,Hast}$[%]	σ_{irr} [Mpa]	$t_{Hast.}$ [μm]	t_{Cu} [μm]	width [mm]
SSTC 2303-105	186	0.51	0.55	701	52	22	4
Tape #1	204	0.41	0.48	633	49	25	4
Tape #2	162	0.58	0.62	899	39	13	4

- The reversible part of the Tape#2 and SSTC exhibits parabolic behaviour, while Tape#1 shows a linear dependence.
- The ReBCO layer typically degrades before the substrate reaches its yield strain.
- Small improvement in the critical current (≤2%) in the unloaded configuration after loading for Ic measurements.
- Tape#2 critical field criterium is 10 μV/m instead of 100 μV/m .

Conclusion

- A new setup for stress-strain measurements of HTS superconducting tapes at RT and 77K has been developed.
- The setup can also measure the critical current as a function of the applied stress and strain.
- Performed measurements are in agreement with literature and data provided by the manufacturer.