Tue-Mo-Po2.09-06 [68]

Mechanical and electro-mechanical investigations of assembled HTS CroCo triplets

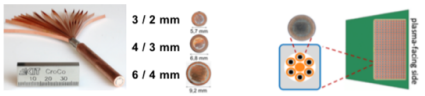
D.S. Nickel, M.J. Wolf, K.-P. Weiss, W.H. Fietz

Institute for Technical Physics, Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

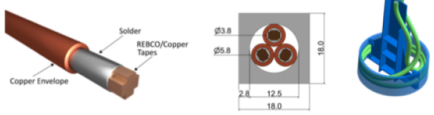
Institute for Technical Physics
Hermann-von-Helmholtzplatz 1
D-76344 Eggenstein-Leopoldshafen
www.itep.kit.edu

Intro and Motivation

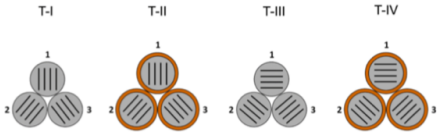
- HTS CroCo can offer a round outer form with inner cross-shaped cross-section for HTS and stabilizing Cu to maximize HTS content. An outer Cu-envelope can serve as electrical & mechanical stabilisation.
- Different HTS CroCo sizes are available and series of HTS CroCo were fabricated with lengths up to 8 m
- Target is a HTS TF fusion coil cable e.g. with 6 HTS CroCo around a central Cu rod (I_{op} = 50 kA, T_{op} = 4.5 K) or application in DC power networks



- To test HTS CroCo as a strand for a high-current, high-field conductor for fusion magnets, a winding demonstrator formed from three cabled HTS CroCo shall be tested at high field

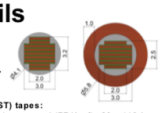


- As a pre-test, transversal pressure experiments are necessary to determine the behavior of cabled HTS CroCos under external high Lorentz forces.
- Triplets of HTS CroCos without and with outer Cu envelope (ø 6x1 mm soft Cu) were investigated in following configurations:



Experimental Details

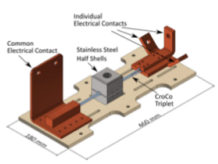
- HTS CroCo were fabricated using 3 mm & 2 mm REBCO tapes* with intermediate copper



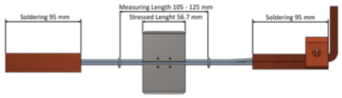
* **Shanghai Superconductor Technology (SST) tapes:**
3 mm: ST 1706-07/08/12 and 1708-09/13 d~ 90 µm I_c(77 K, sf): 90 – 118 A
2 mm: ST 1706-13/14/ and 1708-28 d~ 90 µm I_c(77 K, sf): 60 – 80 A

Triplet	Width	Thickness	Number	CroCo I_c (77K, sf)	CroCo I_c (4.2 K, 12 T)
T-I & T-III	3 mm / 2 mm	~ 90 µm	12 / 6	1.050 A	3.400 A
T-II & T-IV	3 mm / 2 mm	~ 90 µm	10 / 4	870 A	2.700 A

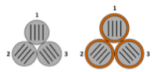
- The CroCo triplet was investigated at 77 K in the MTS-100 experimental setup of CryoMaK. A max. force of 38 kN was applied via two half-shells. A total max. current of 3.500 A was available via a common contact on one side and three individual contacts with identical series resistors on the other side to feed the same current to each of the three HTS CroCos. The individual currents of the parallel connection were measured using a current probe. The series resistors were large enough to neglect the voltage drop along the HTS CroCo at E_c = 1 µV/cm, the criterion to determine j_c.



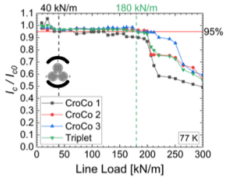
- The loaded length along the triplet was 56.7 mm, the voltage signal was taken over a length of 105 to 125 mm

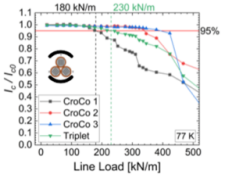


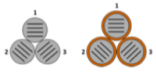
Results and discussion



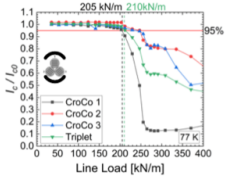
- For the configuration T-I and T-II, the applied force presses the upper CroCo 1 down towards the two lower CroCos 2 & 3 with the main stress parallel to the REBCO tape plane.
- In T-I configuration (without the surrounding Cu envelope) the I_c of CroCo 1 is reduced to 95% already at 40 kN/m and degrades further with increasing line-load. At 180 kN, the overall triplett I_c is reduced to 95%. In T-II configuration (with Cu envelope) the reduction of j_c of CroCo 1 is shifted to 180 kN/m and the overall I_c of the triplet to 230 kN/m.

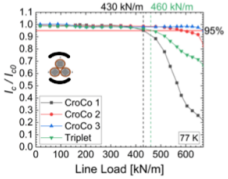






- For the HTS CroCo orientation T-III and T-IV, the applied force presses the upper CroCo 1 down towards the two lower CroCos 2 and 3 with the main stress perpendicular to the REBCO tape plane.
- In T-III configuration (without surrounding Cu envelope) the I_c of CroCo 1 is reduced to 95% at 205 kN/m and degrades fast with increasing load. As a consequence, the I_c of the overall triplet is reduced to 95% at 210 kN/m. In T-IV configuration (with Cu envelope), the 95% reduction of I_c of CroCo 1 is shifted to 430 kN and the overall reduction of the I_c triplet to 460 kN/m.





- Checking the triplet cross-section after the highest loads, reveals massive damages including delamination in case of the CroCo orientation T-I without outer Cu-envelope. For T-II with the Cu-envelope, the damage is substantially reduced

- The same result was found for T-III and T-IV

- Obviously, the outer Cu-envelope reinforces the HTS CroCos and allows the triplet to withstand higher forces

Summary and Outlook

- I_c reduction of different HTS CroCo triplet configurations was examined under transversal load to simulate Lorentz forces.
- The configuration T-I and T-II with HTS tape plane parallel to the main force direction is more sensitive to the applied stress compared to the configuration T-III and T-IV.
- The configuration T-I without outer Cu envelope shows fast I_c degradation to 95% already at a line force of 40 kN/m, whereas T-III shows the same degradation at 205 kN/m.
- In the T-II and T-IV configuration with outer Cu-envelope the I_c reduction to 95% is shifted to 180 kN/m and 430 kN, respectively.
- **The outer Cu-envelope is essential to reinforce the HTS CroCo, but additional measures will be necessary to withstand cyclic loading.**
- To consider the Lorentz forces in a fusion conductor (e.g. 50 kA at 12 T), the accommodation of the cable layout to these forces is essential.
- Alternative layouts e.g. for the triplet configurations examined in this presentation can help to avoid local overstresses caused by point contacts. An example for such a layout is shown in M. Wolf et al., "Design and analysis of HTS subsize-conductors for quench investigations towards future HTS fusion magnets", submitted to CRYOGENICS_2019_232