Investigation of HTS CrossConductor Joints, Connectors and Terminations

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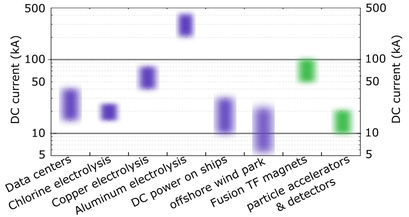
Motivation: High Current DC Applications

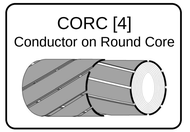


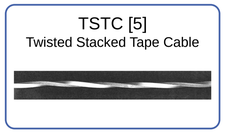
High-Temperature Superconductors (HTS) can improve the energy-efficiency of many industrial high-current DC applications [2]

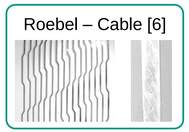
HTS conductors need sufficiently low-resistive terminations and easy-to-fabricate joints.

High-Current HTS Conductor Concepts

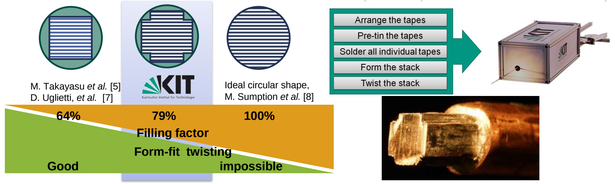
CORC [4]	TSTC [5]	Roebel – Cable [6]
Conductor on Round Core	Twisted Stacked Tape Cable	







HTS CrossConductor (HTS CroCo) [3]



- The HTS CrossConductor is a modified TSTC conductor, where tapes of two different widths are used to improve the filling of the round cross-section.
- The fabrication of the twisted and soldered cross-shaped stack is done in one single, continuous process, allowing the easy fabrication of long lengths.
- The HTS CroCos in this study were fabricated from 10 x 4 mm and 20 - 22 x 6 mm wide *RE*BCO tapes with thick electroplated copper (tape thickness ~165 µm).
- Critical current of one HTS CroCo: I_c(77 K, sf) ~ 3.0 kA

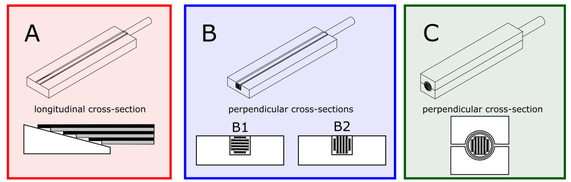
HTS CroCo Terminations

HTS CroCo terminations of 120 mm length and varying degree of complexity are designed and investigated.

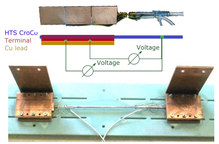
A The HTS tapes are shortened individually (here by 4mm each) to form a stair, which is soldered to an obliquely (3°) grooved copper connector piece.

B The HTS stack is soldered as a whole to a notched copper piece with tapes parallel (B1) and perpendicular (B2) to the connecting plane.

C The HTS CroCo – including the surrounding copper tube - is soldered to the terminal piece.



Measurement Configuration

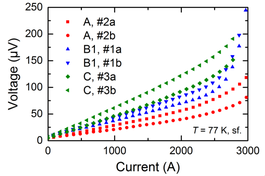


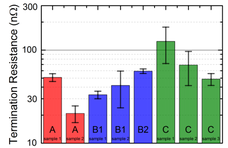
Current is injected to the terminals from the bottom side with leads of same length as the terminals.

Two voltage taps were soldered to the bottom side of the terminal blocks 4 cm from the terminal ends.

Resistance values and uncertainties are calculated as the mean value and standard deviation of these two measurements. Measurements are at T = 77 K, sf.

Experimental Results





A + lowest termination resistance of all samples (21 nΩ for sample 2)
- time-consuming to prepare.

B + Reasonably low resistive terminations (~ 35 – 60 nΩ)
Tapes parallel to the connecting plane (B1) allows current injection from both sides

C + very easy to prepare
- highest resistances (due to the geometry and the increased number of interfaces)

Angular Connectors with Small Bending Radius

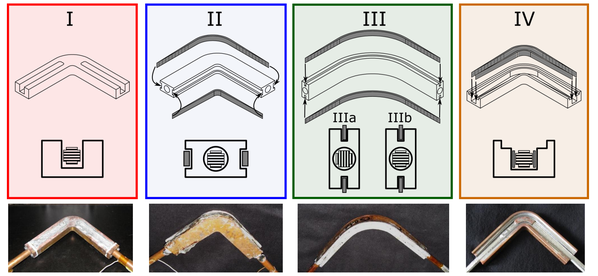
- Four different ways to connect two HTS CroCos with small bending radii (≤ 5 cm)
- HTS CroCo ends are not modified to facilitate the industrial in-field use.
- The contact length on each side is 50mm (III) and 60 mm (I, II, IV)

I HTS ends are soldered to an angular Copper piece with R = 15 mm.

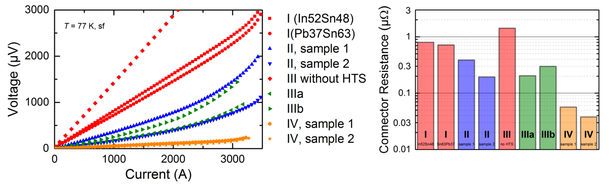
II The connector is equipped with two additional staggered HTS stacks on the outer sides of the connector

III similar to II but with different orientation of the connector and stacks and larger bending radius (50mm)

IV The HTS stacks are on the inner side walls of the connector, thus being in direct connection with the HTS CroCo ends.



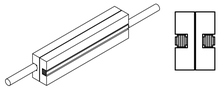
Experimental Results



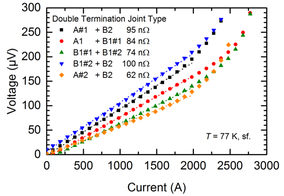
- The use of staggered HTS stacks in connector pieces lowers significantly the connector resistance.
- Lowest resistances of only 38 to 57 nΩ were realized for connector IV, where the tapes are in direct contact to the HTS CroCo ends.
- But even with HTS tapes soldered to the outer sides of the connector (II & III), resistances of 200 – 400 nΩ are achievable for contact lengths of 50 – 60 mm.

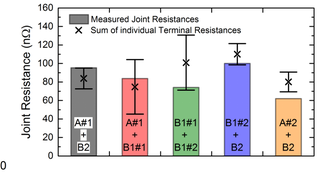
HTS CroCo Double-Termination Joints

Two of the terminations A and B are soldered back-to-back with In52Sn48 solder.



Experimental Results





- Joint Resistances below 100 nΩ are achievable for a joint length of 12 cm.
- The resistance of the Double-Termination-Joints is essentially the sum of the individual terminal resistances.

Conclusions

Easy to fabricate, high quality HTS CroCo terminations

The soldered stack termination (B) is the best compromise for HTS CroCo terminations balancing a low terminal resistance and efforts for terminal fabrication.

Angular connector pieces with small radius and low resistance are feasible

The resistance of HTS CroCo connector pieces can be significantly lowered by using HTS stacks to transfer current between the ends. Lowest resistances are obtained with tapes in direct contact to the HTS CroCo ends (IV), but already HTS stacks at the outer sides (II, III) reduce the connector resistance significantly.

References

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