Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute for Technical Physics (ITEP)

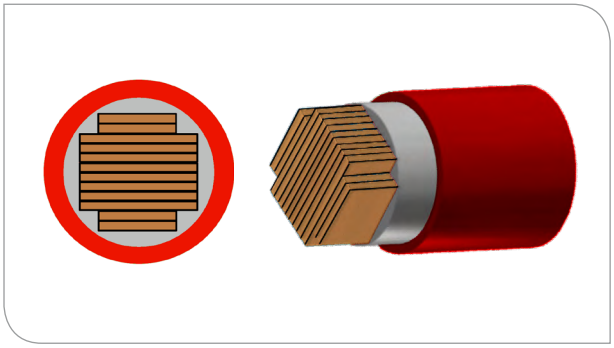
High-Temperature Superconductor – HTS CroCo

An Energy-efficient DC High-current Conductor

Superconductors can transport electrical current at low temperatures, usually below 25 K (-248°C) without any losses. For operation at comparably high temperatures, HTS CroCo is based on a special material. Rare-earth barium-copper oxides, REBCO for short, enable loss-free current transmission in e.g. liquid nitrogen (LN_2) at a temperature as high as 77 K (-196°C). HTS CroCos allow energy-efficient and environmentally compatible solutions for the generation of high magnetic fields or the transport of electrical energy.

Manufacture of HTS CroCo

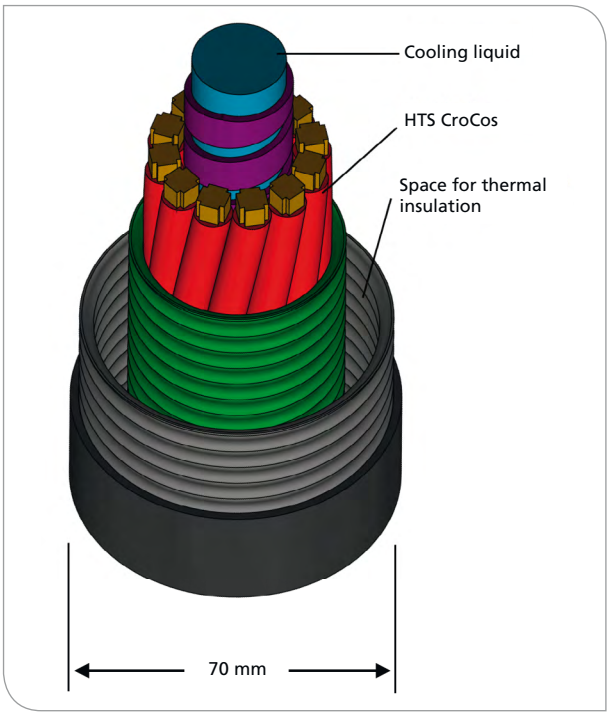
By means of a KIT-developed process, the so-called high-temperature superconductor (HTS) cross conductor (HTS CroCo for short) can be produced from several REBCO tapes. The manufacturing process is designed for large lengths and industrial production. In 2016, it was granted an award by the EU. Up to 60 HTS tapes of two different widths are stacked and soldered along the complete length. The result is the cross-shaped cross section, after which the conductor is named. The shape was chosen to achieve a high superconductor content and the associated high transport current in the round cross section. The conductor can then be twisted to improve the magnetic properties and packed into a copper pipe. The resulting round cable facilitates further processing.



Setup of a HTS CroCo

Basic Unit for High-current Cables

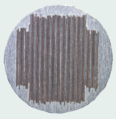
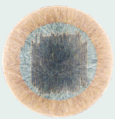
An HTS CroCo produced from 4 and 6 mm wide REBCO tapes has a diameter of 9.7 mm, only. At a temperature of 70 K, which may be reached by cooling with LN_2, it can transport a direct current of more than 4,000 Ampere without any losses. When cooled with liquid hydrogen (LH_2), a current well above 20,000 A is possible. High-current cables may be produced by combining several HTS CroCos. In 2018, KIT built and operated a demonstrator that carried a current of 35,000 A at 77 K. Compared to conventional domestic fuses that are able to carry 16 A, this corresponds to the current of 2,100 of such fuses. An optimized cable of 12 HTS CroCos may have a diameter of not more than 70 mm, including thermal and electrical insulation, as shown below.



Cable with a maximum current of 35 kA at 70 K

HTS CroCo Designs

Apart from the mentioned tapes of 6 and 4 mm width, HTS CroCos can also be manufactured in other sizes. The table below lists as examples the tape widths, number of tapes, lengths of the cross diagonal, and the maximum transport currents I_c of three HTS CroCos. With decreasing temperature, higher transport currents can be reached and transmitted even at strong magnetic fields. The large variety of possible configurations allows to adapt the HTS CroCos to different applications.

	6/4 CroCo	4/3 CroCo	3/2 CroCo
			
Typical number of REBCO tapes	22 x 6 mm 10 x 4 mm	28 x 4 mm 10 x 3 mm	18 x 3 mm 10 x 2 mm
Cross diagonal	7.2 mm	5.0 mm	3.6 mm
I_c T = 77 K, self field	3 100 A	2 090 A	1 460 A
I_c T = 30 K, B = 2 T	20 000 A	14 000 A	9 000 A
I_c T = 4 K, B = 12 T	> 10 000 A	~ 9 500 A	6 000 A

HTS CroCos of variable sizes with and without a copper sleeve

Application Examples

HTS CroCos can transmit very high DC currents while considerably saving space and weight in comparison to conventional copper or aluminum cables or rails. The biggest advantage, however, consists in loss-free energy transport by the superconductor and the associated environmentally compatible and energy-efficient solutions for generating highest magnetic fields or transporting electrical energy. When cooled with LH_2, chemical and electrical energy can be transported in parallel. Other applications for HTS CroCos are power transmission for wind parks, DC power supply on ships, compact and lightweight high-power cables in future electric airplanes or power supply for electrolysis (up to 300 kA).

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