

EuCARD2 10.3

HTS Dipole Design Studies

03/02/2014

“Agenda”

- Design layouts studies
- Open issues
 - « Field quality » conductor
 - Conductor insulation
 - Winding behavior
 - Mechanical characterization
 - Roebel cable impregnation
 - Test coil
- Actions list
- Meetings

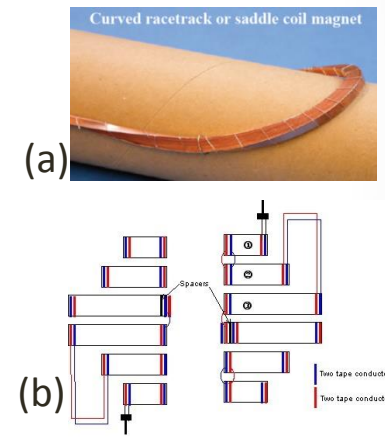
Design layouts

D10.1, Conceptual study of HTS accelerator magnets → Nov 2014

- YBCO Roebel cable
 - Sheared block design → CERN
 - Cosine-theta design → CEA
- YBCO Stacked cable
 - Block design → INPG
 - Cosine-theta design → CEA ?
- BSCCO Rutherford cable
 - CCT design, 8-strands cable → LNBL + CERN
 - Cosine-theta design, 8-strands cable → LNBL
 - Cosine-theta design, 28-strands cable → CEA and/or LNBL
 - Block design → Texas A&M ?

“Field quality” accelerator cable 1

- high J_c conductor, high JE cable
 - JE ($B \perp 20T$, 4.2K) = 600 A/mm² (actual baseline) → 400 A/mm² (new baseline?)
- field homogeneity, low AC losses → transposed cable configuration
 - ok for BiSCCO Rutherford cables
 - Ok for Roebel cables ? → current distribution studies
 - for stacked tapes cable, cable transposition is proposed
 - (a) at coil ends
 - (b) pole-to-pole
 - → Need for AC-losses measurements on tapes and stacks
 - → Need for transposition modeling
 - Geometry dependence
 - positioning defaults impact
 - Need for fully twisted stacked tapes?
- precise and controlled dimensions
 - an issue for YBCO Roebel? → Need for cable characterization, winding tests
 - an issue for twisted stacked tapes? → twist region configuration studies
 - ok for BiSCCO Rutherford cable? (HT 900°C)

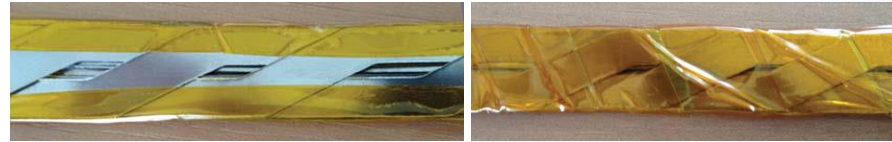


“Field quality” accelerator cable 2

- mechanical strength
 - An issue for non impregnated Roebel cables
 - An issue for twisted stacked tapes
 - → Need for cable mechanical modeling
- mechanical stability
 - An issue for Roebel cables → support, impregnation
- windability (bending radius)
 - Ok for BiSCCO Rutherford cable
 - To be demonstrated for YBCO cables
 - Tensile stress limit
 - Bending behavior → J_c degradation, delamination
- protection
 - Need for high current cable
 - Acceptable minimal value 5kA ? Source ? Calculation hypothesis?
 - Need for Copper stabilizer

Conductor insulation

- Insulation candidates - YBCO cable
 - Polyester coating (EuCARD HTS insert) ?
 - Kapton ?
 - Polyester heat shrink tubing ?



Polyester heat shrink tubing from Advanced Polymers, Inc., used for Y10-04 test coil at NHMFL

- Glass fiber tape ? → compatible with cable impregnation
- Insulation candidate - BiSCCO cable, 900 °C HT compatible
 - Glass fiber tape ?
 - TiO₂-PPC?

Winding behavior – Roebel 1

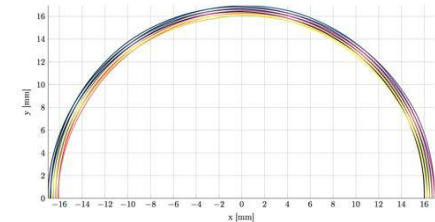
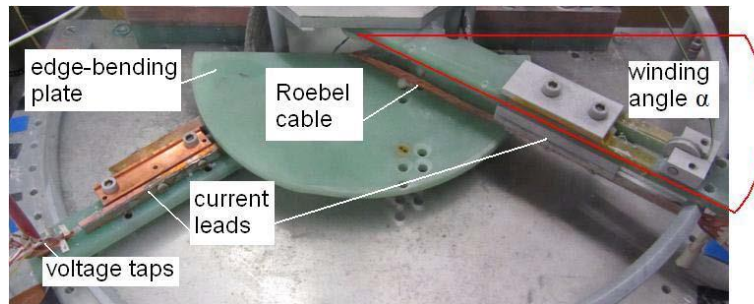
- Bending properties

- easy way bending (out of plane)

- at CERN (J. Fleiter) : $R > 4 \text{ mm}$
- at CERN (Jeroen): $R > 11 \text{ mm}$ for KIT cable → Studies on link between transposition pitch and bending radius



- at KIT



- hard way bending (in plane)

- $R > 900 \text{ mm}$ (J. Fleiter)
- $R > 2\text{m}$ (Jeroen, GC cable)



Winding behavior – Roebel 2

- Cable handling, winding procedures
 - studies starting at CEA
 - tension stress limit ?
 - From Bumby et al. : Failure axial tensile stress 146 MPa for the meander tape and 113 MPa for the Roebel cable (625 Mpa for the straight conductor)
 - Stress distribution between strands ?
 - Shall we have to stop at tension stress limit of a strand ?

Winding behavior - Stacked tapes

- Bending properties
 - easy way bending (out of plane)
 - $R > 10$ mm (Jérôme Fleiter)
 - hard way bending (in plane)
 - $R > 900$ mm (Jérôme Fleiter)
- Cable handling, winding procedures
 - studies starting at CEA
 - EuCARD HTS Insert

Mechanical characterization – Roebel

- Transverse pressure studies

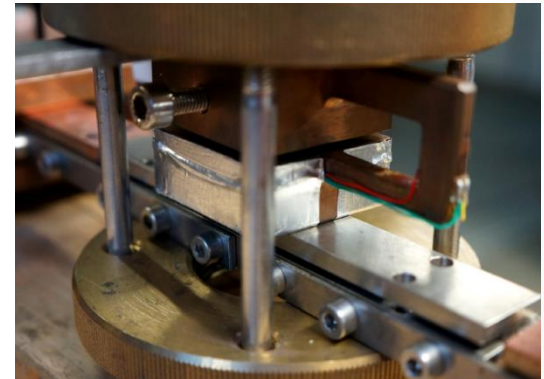
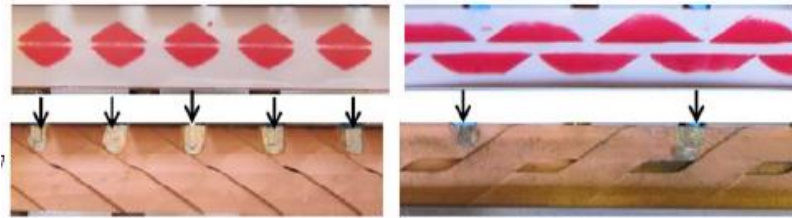
- at CERN (J. Fleiter)

- Non homogeneous stress distribution across the length and across the section (a)
 - Measured **no I_c reduction up to 45 MPa** of average transverse stress

- at KIT (Bayer et al.)

- Measured **10 % reversible I_c reduction starting from 14 MPa** of average transverse stress (b)

- at CERN (J. van Nutgeren, G. Kirby)



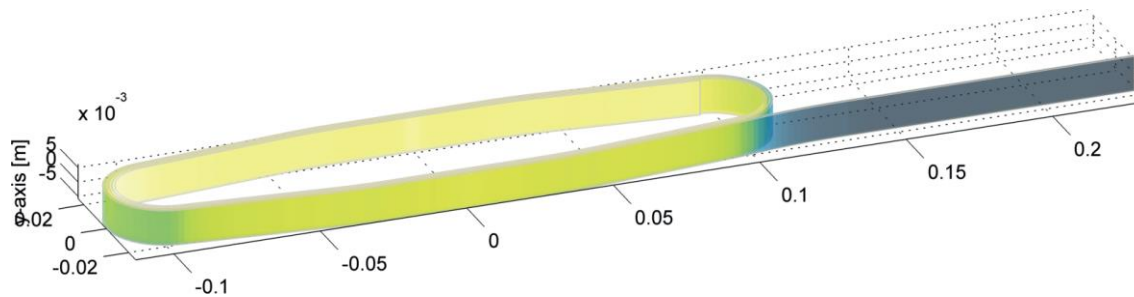
→ Roebel cable impregnation

- Transverse stress reinforcement
 - Copper strips between YBCO tapes
 - Cable impregnation
- at CERN
 - discussion with CTD for fillers,
 - ten stack test campaign : contraction and thermal conductivity, young modulus, contact resistance, breakdown voltage of turn to turn insulation
- at KIT
 - Tests on filler materials together with Twente University
- → Need for Roebel cable modeling
- → Need for dummy YBCO cable to test for delamination issues



Test coil

- SMC type coil ?
- Feather - M0 coil (Jeroen, CERN)



Feather-M0

Purpose - learn winding (mechanical)

Standalone - 0.6/2.0 T (w.o. iron)

In background (13T) - 0.6/2.0 T (w.o. iron)

Number of turns - 4

Operating current - 9.0 kA

Inductance (self) - 4.5 μ H

Straight Section - 40 mm (incl. layer jump)

Cable length - 2.0 m (2 poles)

Aperture/Outer size - 40/69 mm (Fresca-I/II)

Actions

- Conductor design (number of tapes, twist pitch) → task 10.2
- AC-losses measurements on tapes and stacks → Grenoble is checking for tests possibilities at CRETA
- Cable transposition modeling → INPG
- twist region configuration studies → INPG
- Roebel cable mechanical modeling → CEA or CERN
- impregnation → CERN has purchased a set of different resins to evaluate the impact on:
 - Mechanical reinforcement → starting with stainless-steel cable
 - Differential thermal contraction → delamination → need for YBCO cable
 - Contact resistance
- cable characterization, winding tests
 - mechanical tests → CERN
 - winding procedures/ tests → CEA
- quench detection system (CERN, collaboration with Ramesh Gupta?)
- protection : start with new cables modeling ?

Meetings

- EuCARD2 1st Annual Meeting + Workshop on HTS for accelerators
 - DESY Laboratory in Hamburg
 - Monday May 19th to Tuesday May 20th : general sessions
 - Wednesday May 21st to Thursday May 22nd : workshop on HTS for accelerators
- Regular short progress meetings
 - We would like to fix a weekly meeting, a window to merge studies progress done, problems, need for special topics meetings
 - Do not look for everyone to be present
 - A doodle to find the best day/time will be prepared by Maria
 - Only design people could be involved in a first time:
 - CEA: Maria Durante, Clément Lorin
 - CERN : Glyn Kirby, Jeroen van Nugteren, (Gijs de Rijk)
 - INPG: John Himbele, Arnaud Badel, (Pascal Tixador)
 - Others ?
- Special topics meetings
 - Cable configuration/characterization
 - Cable mechanical modeling
 - Cable insulation
 - ...
- Task 10.2 /10.3 meeting : next week – to be fixed

Splices/ Layer jump