Karlsruhe Institute of Technology

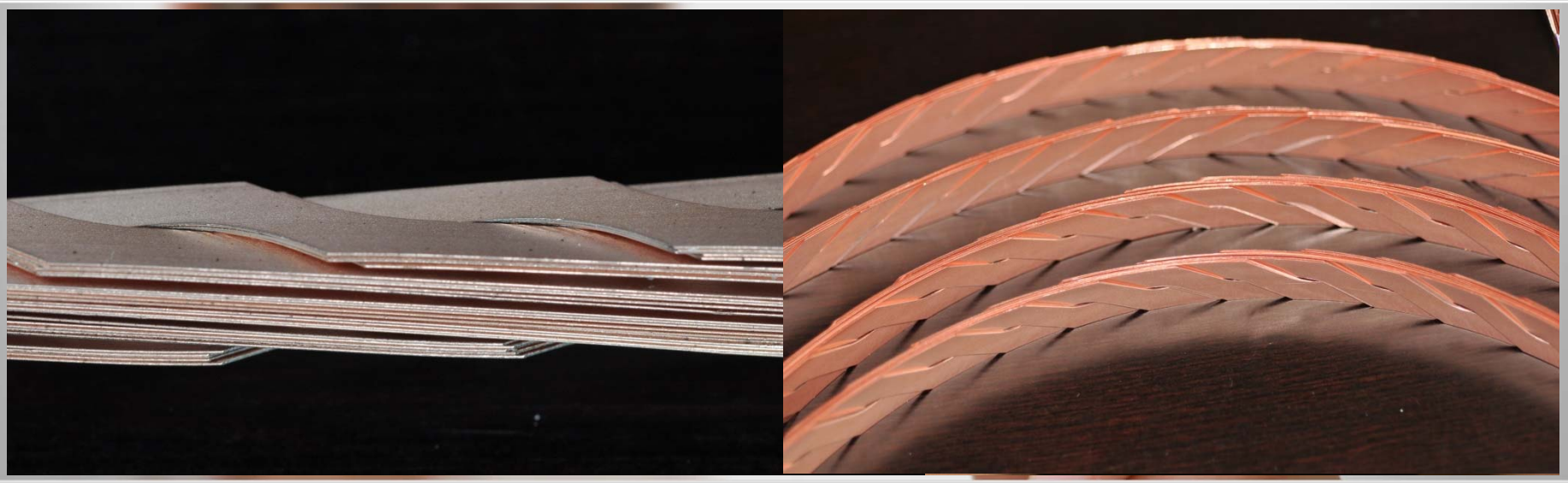
Video-Conference 28th. Jan. 2014

Karlsruher Institut für Technologie

Pro and Cons to RACC- Cables: Roebel Assembled Coated Conductor Cable

W.Goldacker, A.Kario

Institute for Technical Physics (ITeP) – Superconductor Development and Electrotechnical Applications



Overview on activities at KIT with RACC

Karlsruhe Institute of Technology

Activities on RACC

1. **Eucard II specific investigations:**
   * Investigation of bending properties (Tests on simple device + Construction of sophisticated bending rig)
   * Preparations for cable with extended transposition length
   * Test of filler materials for transverse stress reinforcement (together with Uni. Twente)
2. **RACC Cables with filaments**
   * Preparation of samples with striations (widely done)
   * Investigation of AC losses + Modelling (in work)
3. **Rutherford Cable for Fusion magnets with RACC strands**
   * 2.5 kA cable successful = shown at HTS4Fusion – WS)

Pros for RACC - Cable

- Availability of suitable 12 mm conductors from industry is given (Superpower, SuperOx, (Fujikura, Sunam ?, THEVA end of 2014)) Bruker ???
- RTR – punching of Roebel strands with high precision at KIT in all lengths (quality of GC-IRL not sufficient)
- Design successful: 26 m cable produced (GC-IRL), 5 m (KIT)
- Assembling machinery exists at GC-IRL. Installing a KIT approach depends on demand and support (Combining the strength of both laboratories possible !)
- Excellent bending ability: no degradation for R_b > 2 cm (standard RACC design)
- Flexibility of the cable design for increased currents and options:
  - Number of coated conductors strands
  - Transposition length,

* external electrical (Cu-tapes) and mechanical stabilisation possible

Pros for RACC – cable (cont.)

- High engineering currents
- Electrical stabilisation adjustable (Cu layer)
- Option filaments for lowered AC losses when required
- Inherent high mechanical strength of CC (Hasteloy and steel substrates)
- Increasing number of industrial CC companies

Cons for RACC – cable

- Loss of material on strand punching (can be reduced by coating punched substrate tapes)
- Assembling procedure sophisticated (for dense packed material) and long lengths (improvement possible = discussion point !)
- Roebel design requires CC quality without longitudinal defects !
- In-plane bending is a limitation for 3D turns/bents (dipole)
- Conductor costs ! Industrial cable processing costs !

Experience at KIT = arguments for RACC cables

RTR Strand punching

widths: 4 and 12 mm

Transposition flexible:

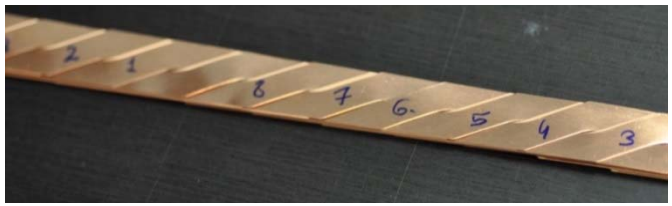
4 mm cable : 115.7 mm

12 mm cable: 125.8, 226, 426 mm

(can be redesigned)

Dense packed cable:

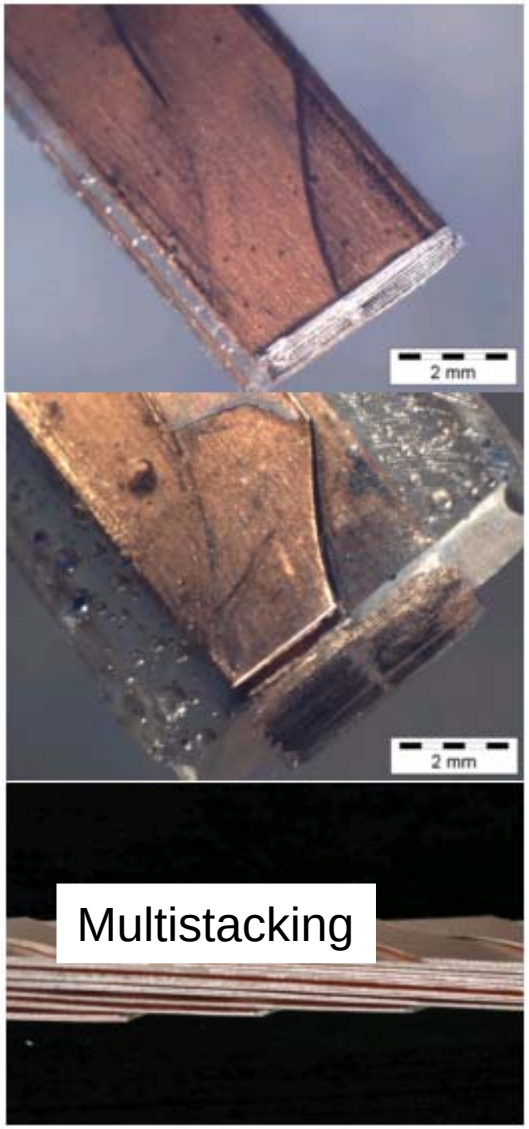
- Good for transverse stress
- However hand assembled



Combination ?

Winding machine for 15/5 cable

Increased I_c by Multistacking



1.) 4 mm cable width, option multistacked strands

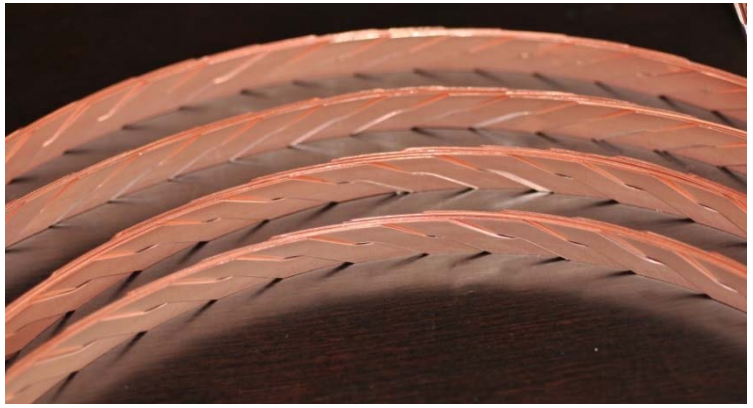
Sample name	Strands	Width (mm)	Thickness (mm)	I_c (A)
R14 × 1	14	4.3	1	465
R13 × 3	39	4.4	2.7	1060
R10 × 5	50	4.4	3.8	1195

I_c = 1.2 kA, 4 mm, SP, transposition 109 mm

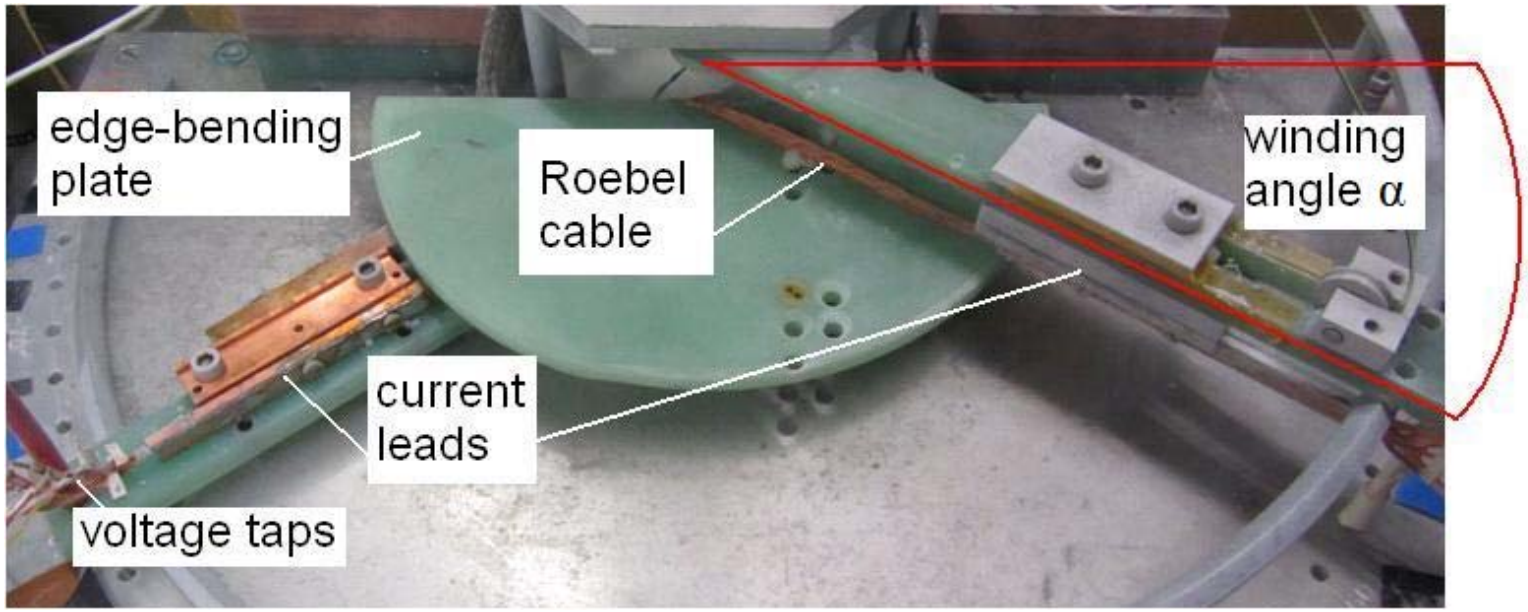
2.) 12 mm cable width, option multistacked strands

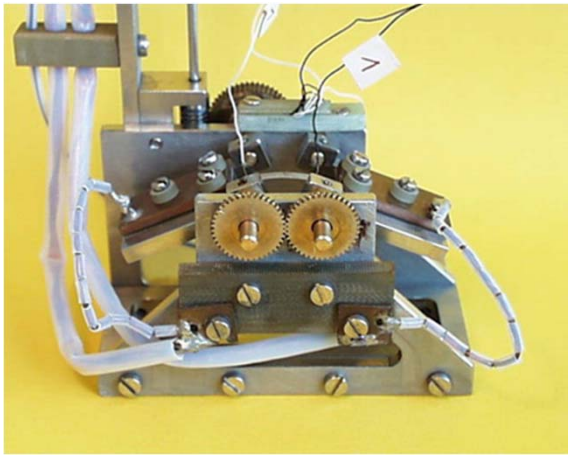
I_c = 1.2 kA (10 strands) – 2.6 kA (45 strands) shown

Length of 5m
for 10 strands



Edge bending of the Roebel-cable:
Continuous edge bending strain rig CEBSR



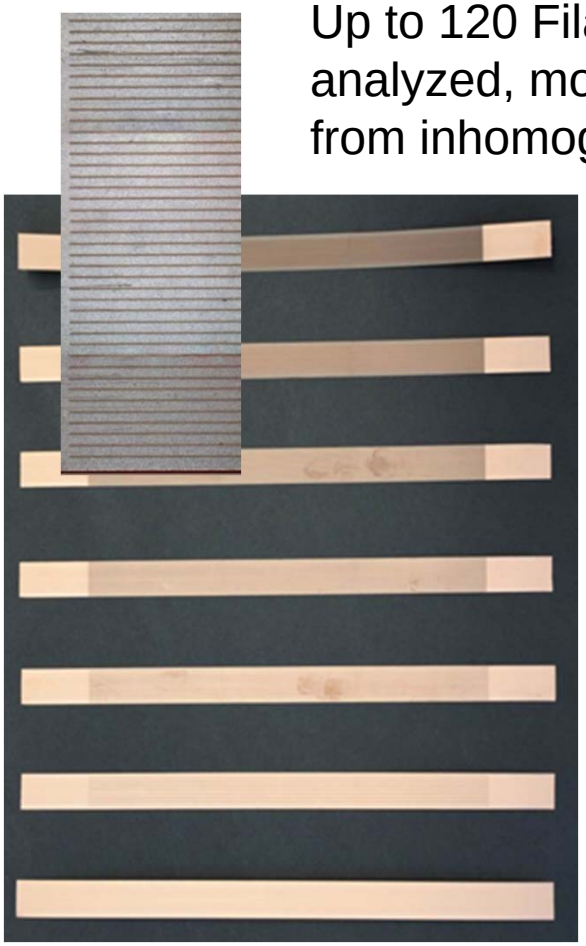


New !
Design for a new very flexible bending rig has started

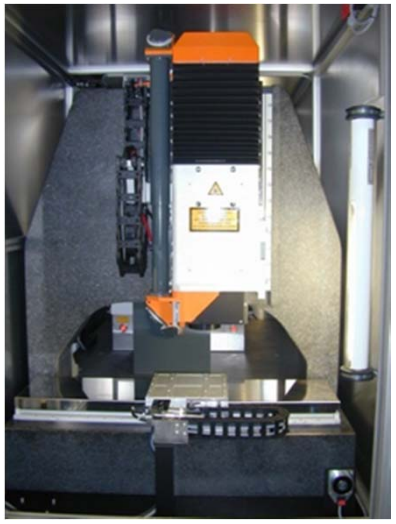
Rig for CC in operation (left side)

Option for low AC losses: Striated CC or strands:

Up to 120 Filaments prepared and analyzed, moderate current degradation from inhomogeneity (to be published)



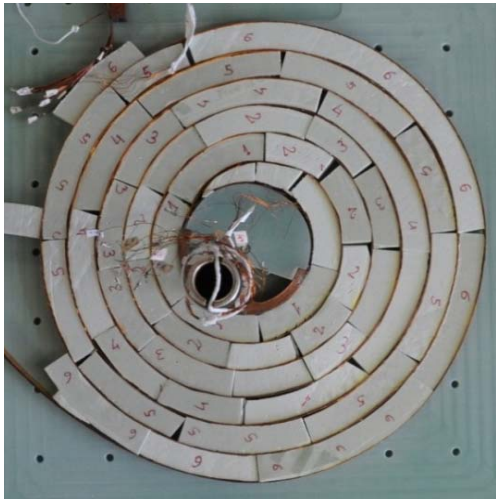
Psec Laser, option is RTR extention (150 k€)

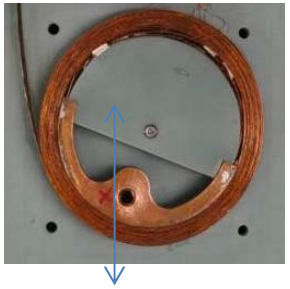


S. Terzieva, M. Vojenčiak, F. Grilli, R. Nast, J. Šouc, W. Goldacker, A. Jung, A. Kudymow, A. Kling, Investigation of the effect of striated strands on the AC losses of 2G Roebel cables, SuST 2011

Pancake and layered RACC coils

- **Experience about handling coil structures**
- **Modeling the coil performance**





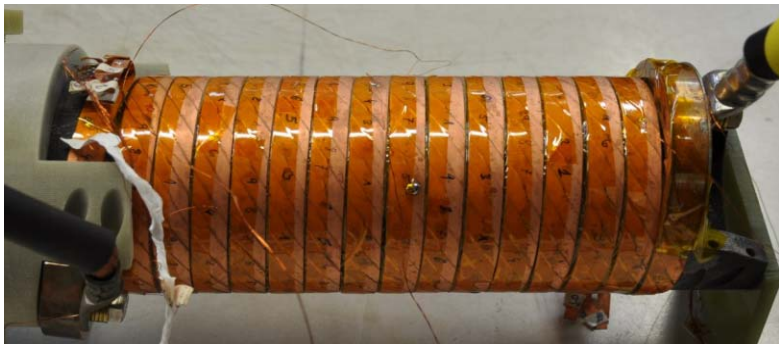
10 cm

Sample data

- **SuperPower CC**
- **Length 5 m, width 12 mm**
- **Strand width 5.5 mm**
- **10 strands**
- **Transposition 126 mm**

spacing(mm)	No. of turns
20	6
10	9
4	9
1.4	11
0.1	13

Spacing (mm)	No. of turns
24	14
18	14
12	15
6	15
1	15



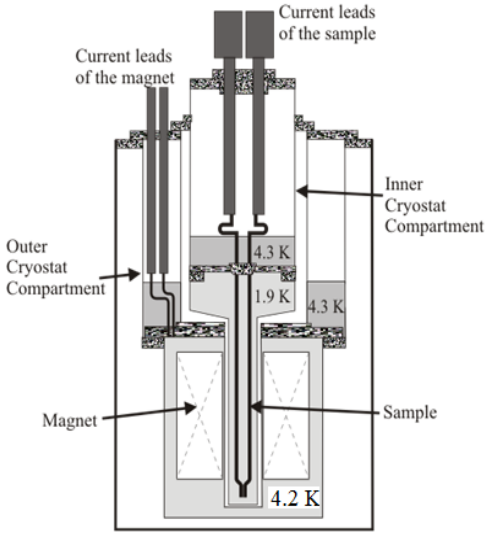
1 sample for all experiments !

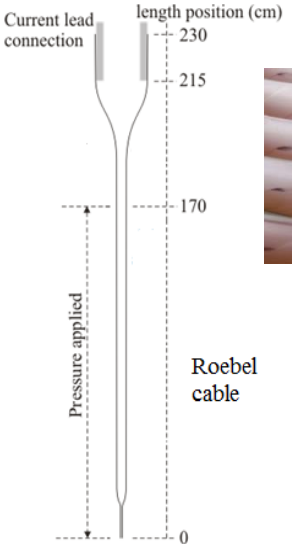
The completely equipped CC-RFC (Rutherford) sample

I_c at 77 K s.f. = 2.5 kA (use of GC material)

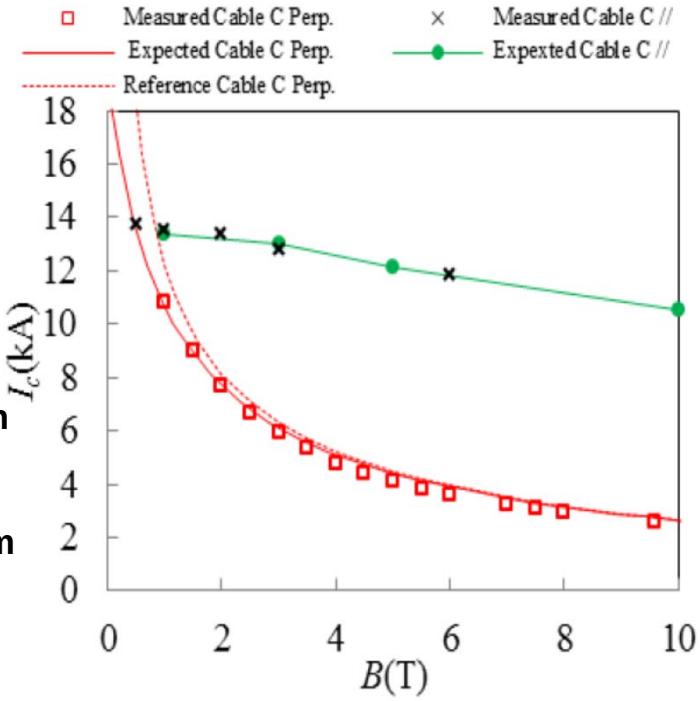
6 strands with 10 CC each and 5.5 mm width

Extrapolation of current capacity increase applying design options for RACC cable





10 strands
12 mm cable width
2 m length
1.1 kA at 77K sf
Transpos.: 126 mm



Electrical characterization of RE-123 Roebel cables
J. Fleiter[1], A. Ballarino[2], L. Bottura[2], P. Tixador[3], Superc. Science &Technol.

Transport currents : 14 kA at self field
4 - 12 kA at 6 T (4.2 K)
anisotropy factor 3

Extrapolation for 0.5 m transposition length (x 4):

16 – 48 kA at 6 T (4.2 K)
+ Multistacking of 2 or 3 CC = multiplier

Concluding comments:

- Decision on CC very urgent !
- Test of best availlable CC quality (highest current) !
- Assess new extrapolation towards specs from this !
- Faster feedback of high field data (CERN) necessary
- Upgrade with impregnations (CEA feedback)
- Decision on which version of upgrade for next cable (transposition, current, material)!
- Discussion on budget limitations depending on …..
- KIT is ready to discuss concentrated efforts with GC-IRL
- KIT is ready to produce dummy for winding tests.