Mechanical Properties of Roebel Coated Conductor Cable

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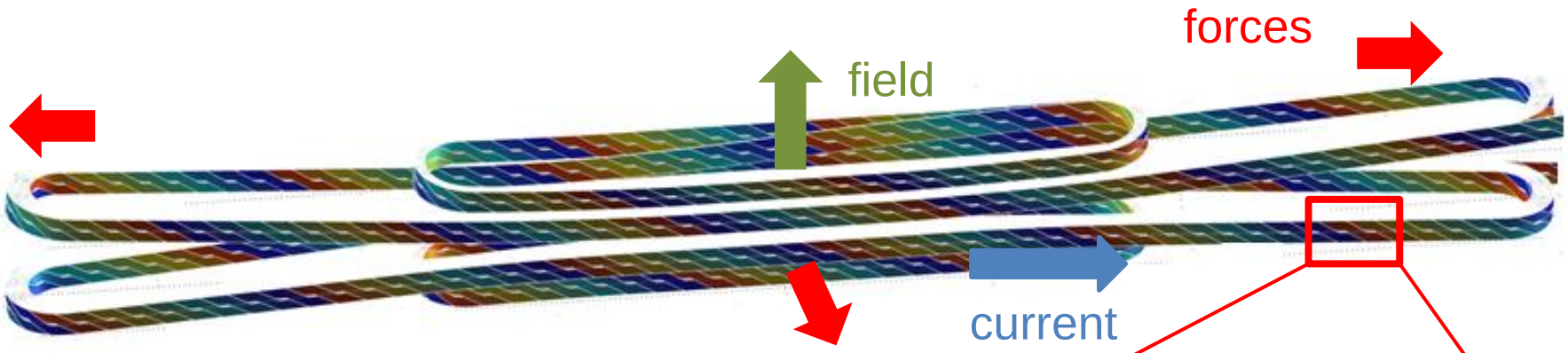
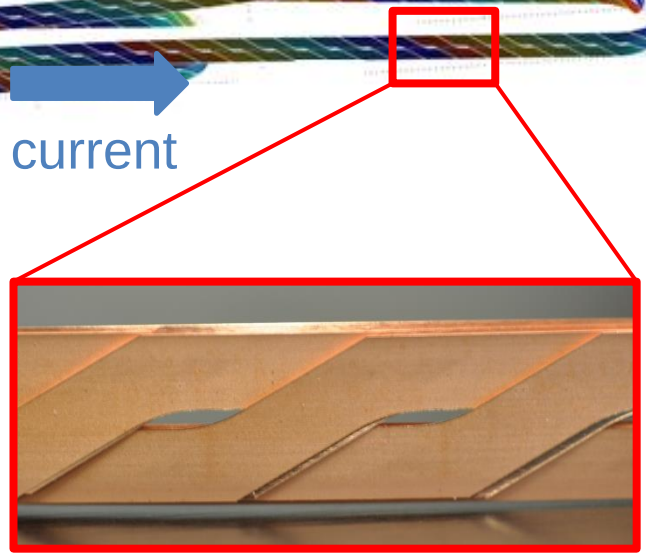
[3] Institute of Electrical Engineering, Slovak Academy of Science

Motivation

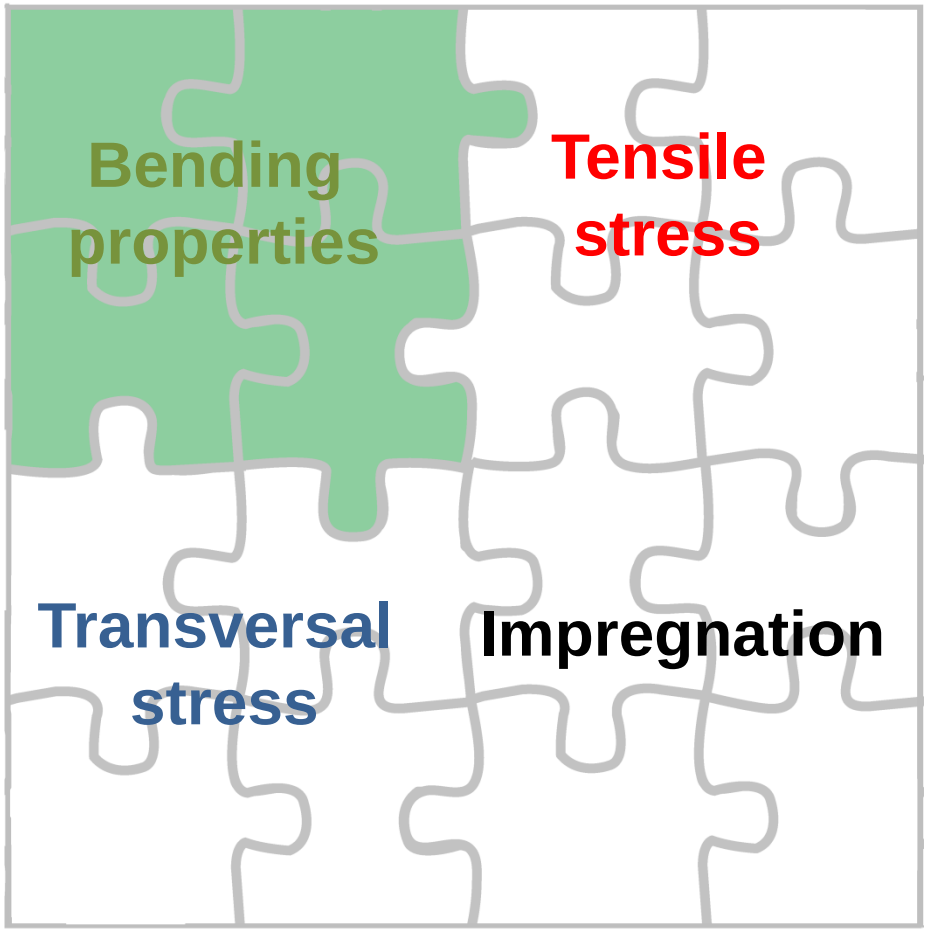


G. Kirby et *al.*, EuCARDII Meeting



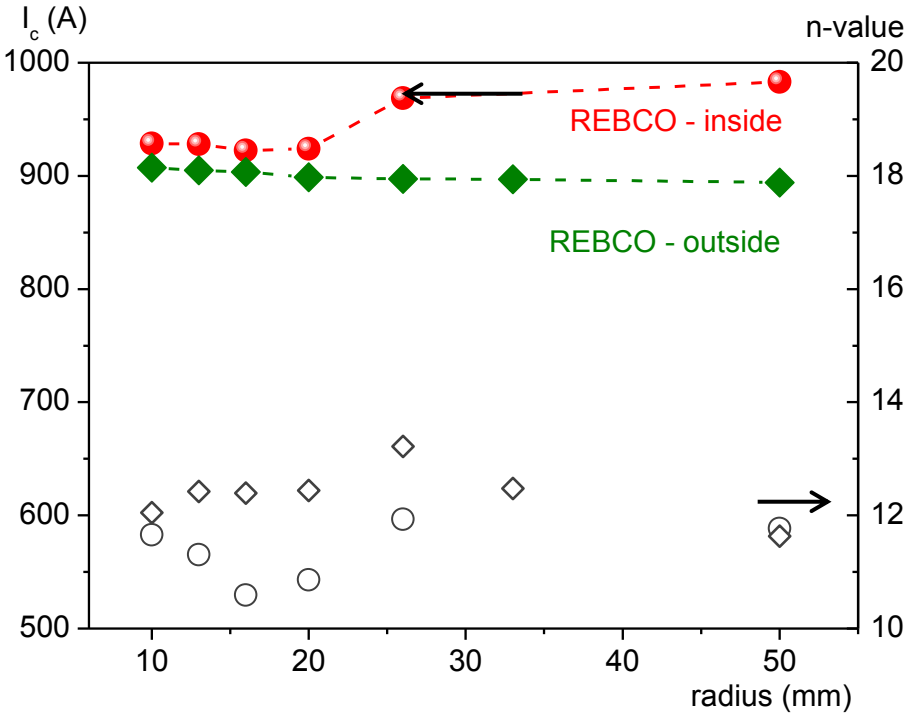
- Bending properties
- Tensile stress
- Transverse stress
- Need of impregnation

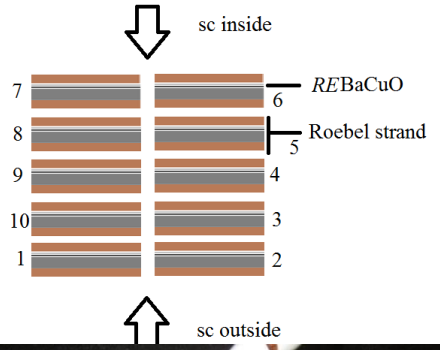
Outline

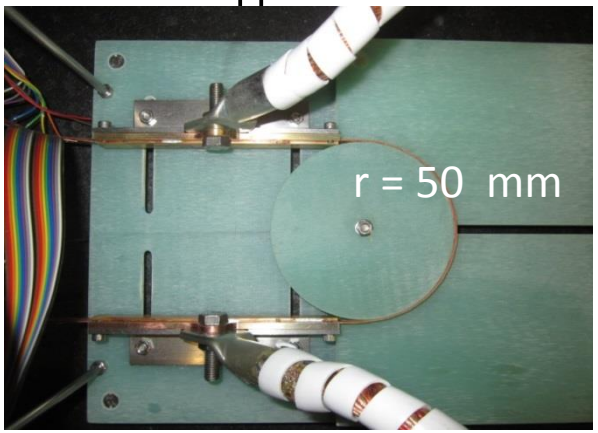

Bending properties
Tensile stress
Transversal stress
Impregnation

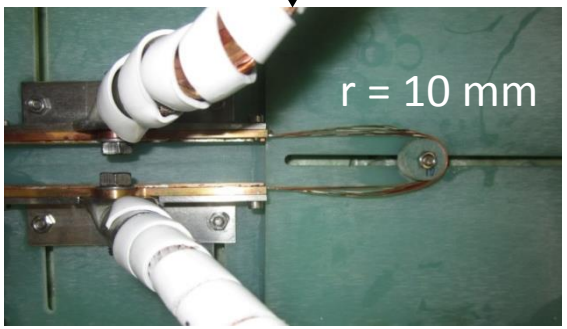
Bending radii > 10 mm do not degrade the I_c

- Cable geometry: 12 mm cable, 10 strands, TL: 126 mm
- Measurements on single strands show degradation in the bent section by < 1%
- Small degradation, < 6.5 % of total cable I_c
- Cable degradation was not caused by bending









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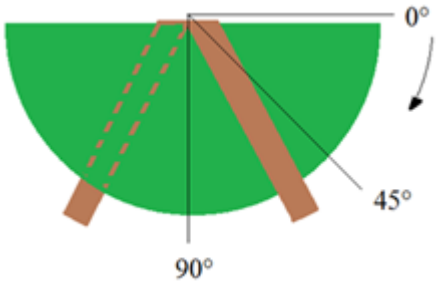
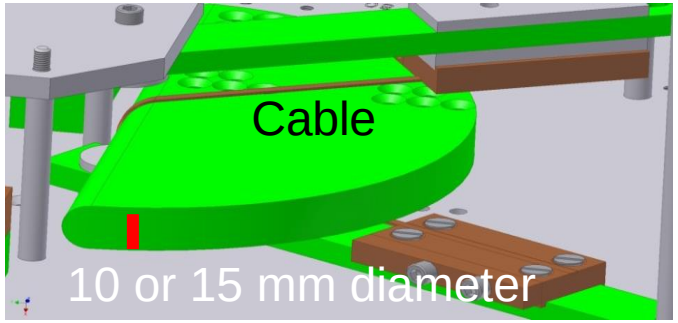
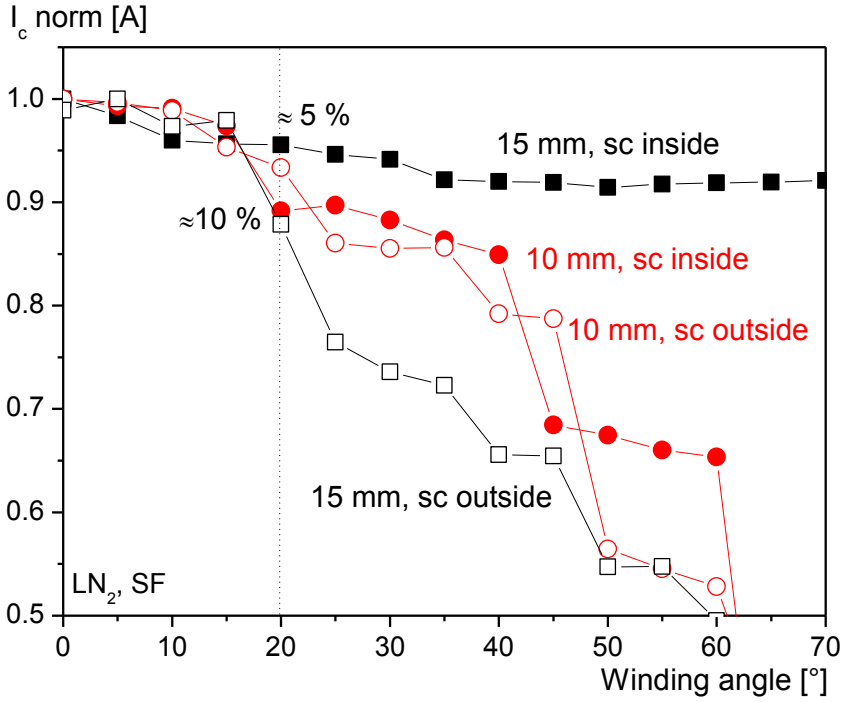
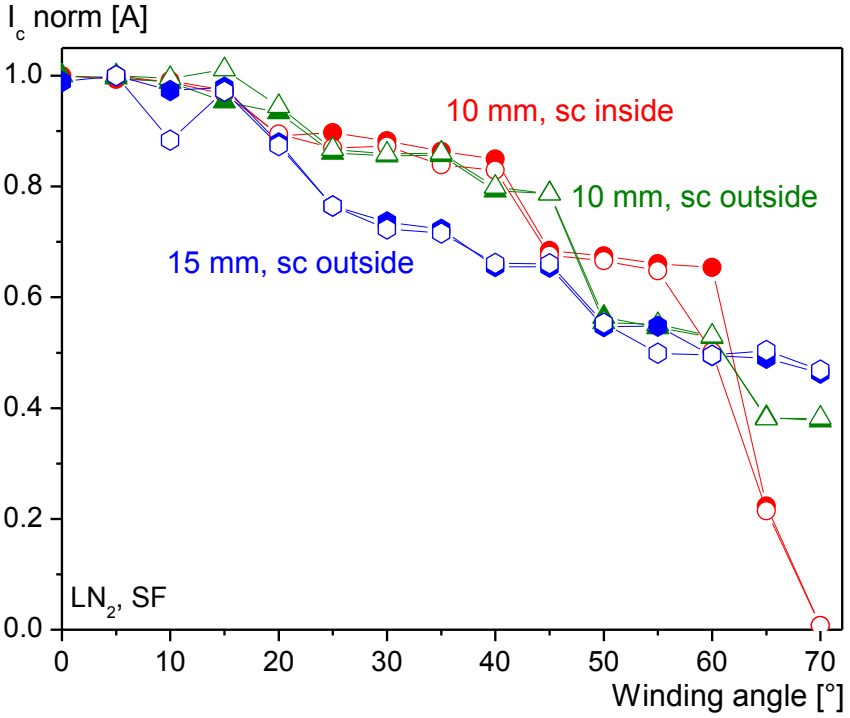
Roebel cable is fragile to bending-torsion



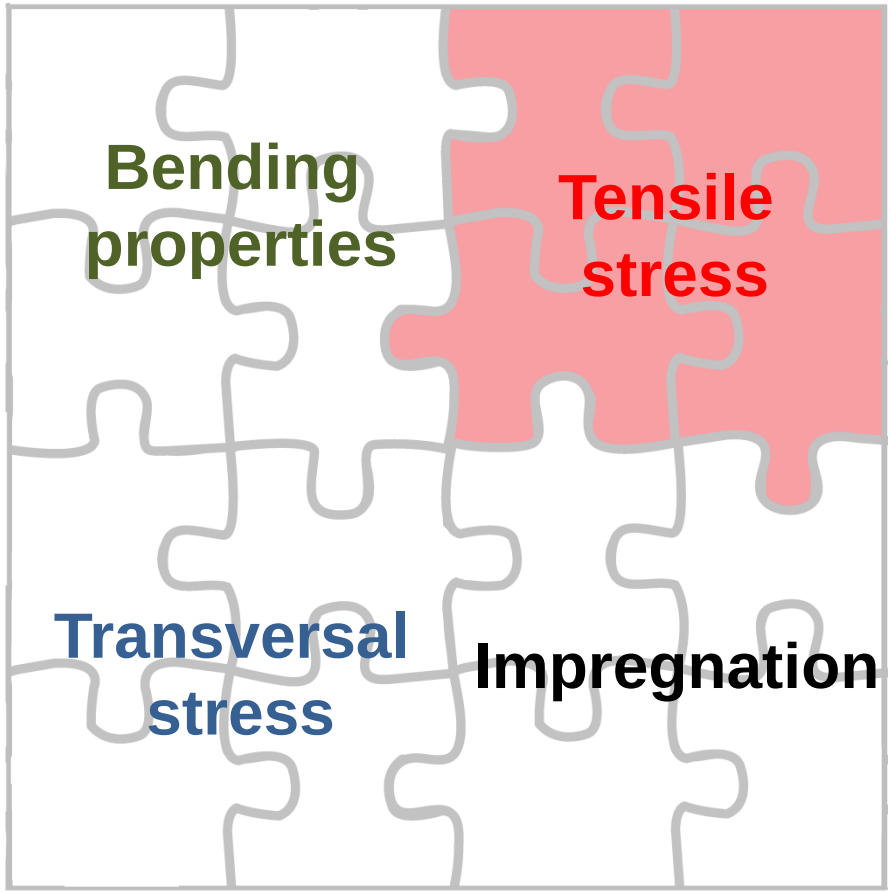




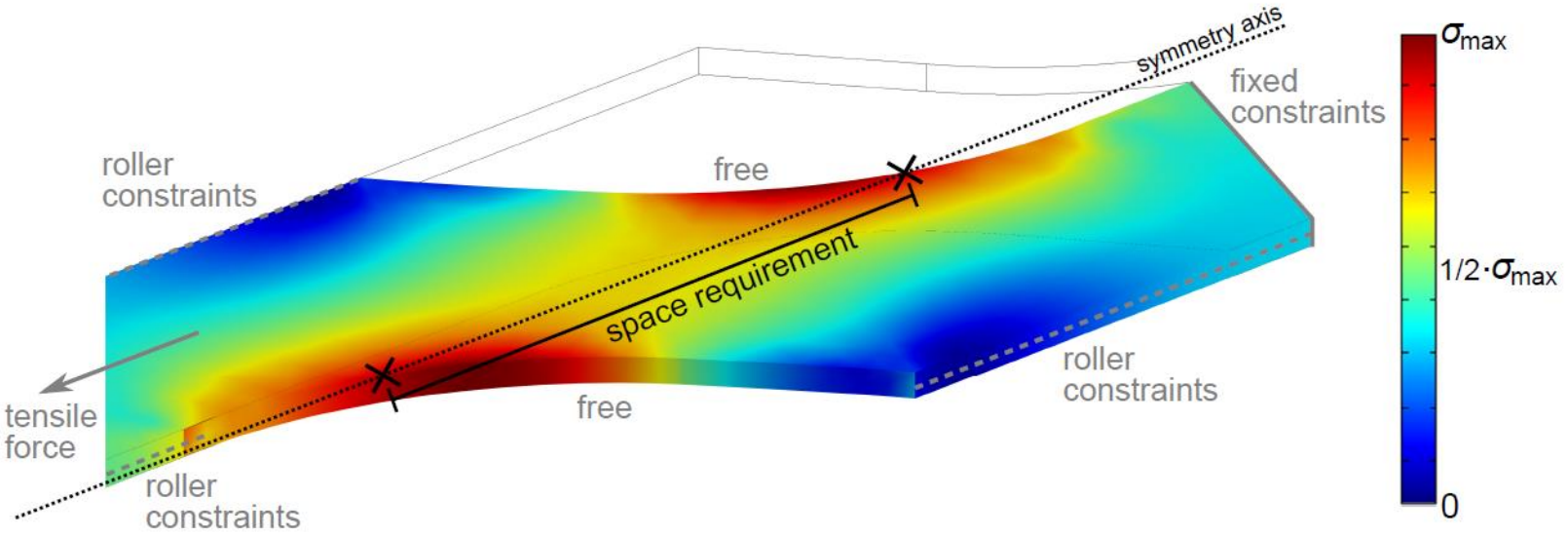


- 5% or 10% degradation at 20° winding angle
- No reversibility in a case of 10 and 15 mm thickness

Outline


Bending properties
Tensile stress
Transversal stress
Impregnation

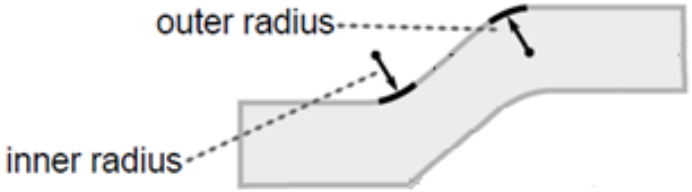
Modelling of the stress in meander structure

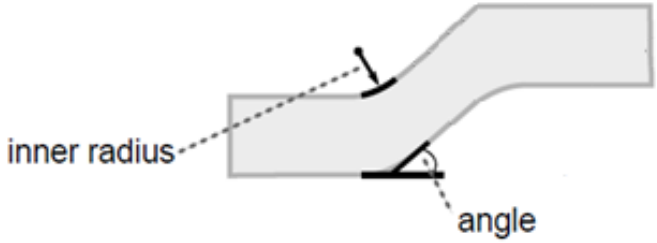


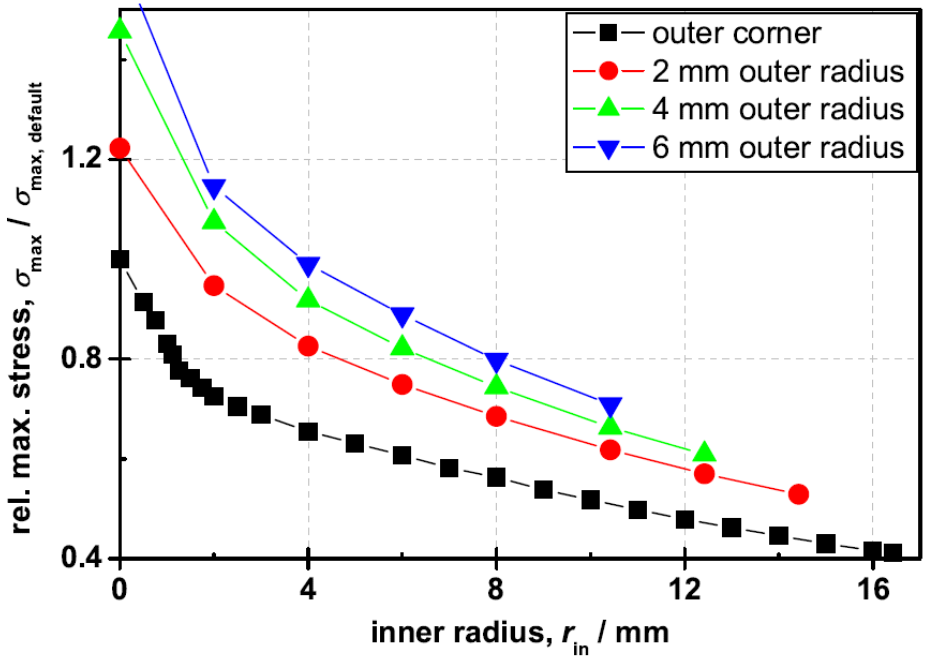
C. Barth *et al.,* Supercond. Sci. Technol. 25 (2012) 025007 (9pp)

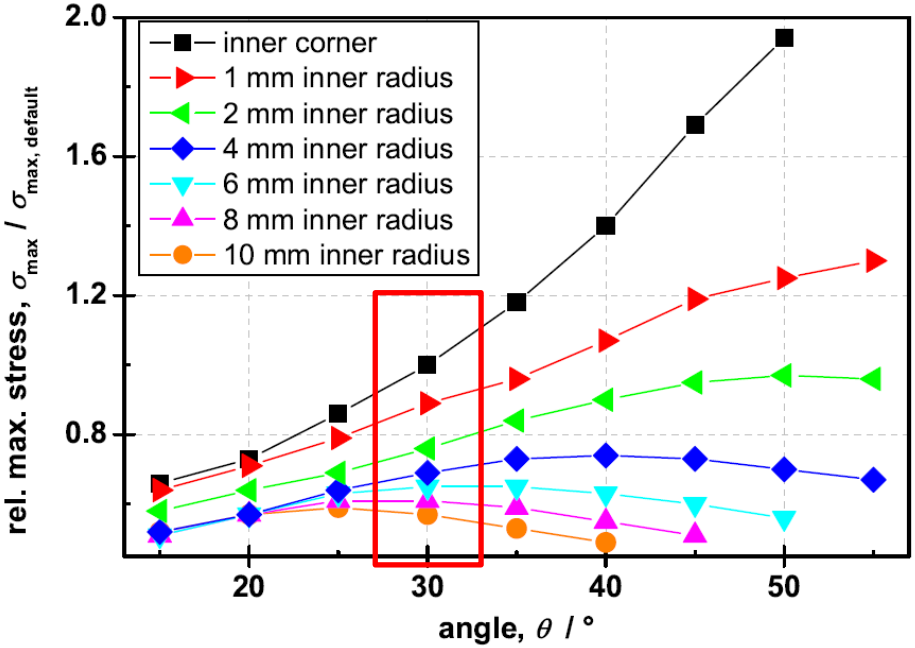
- 4 mm Roebel cable
- Superpower tape: 100 µm thick, Yong modulus: 120 GPa
- Applied tensile load 1 kN
- Finite Element Method, Comsol Multiphysics

Roebel strand geometry: outer corner and 10 mm inner radius





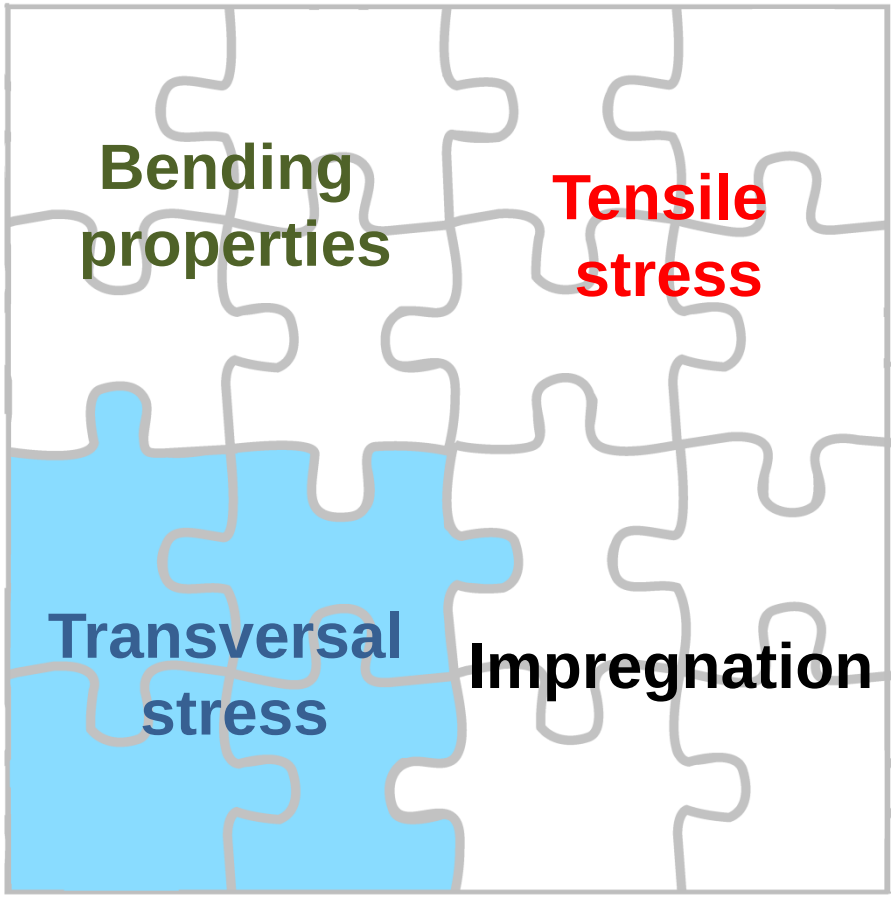




- High von Mises stress – concentrated in small areas, favour the growth of cracks
- Low von Mises stress – distributed over large area, cable can withstand high tensile load

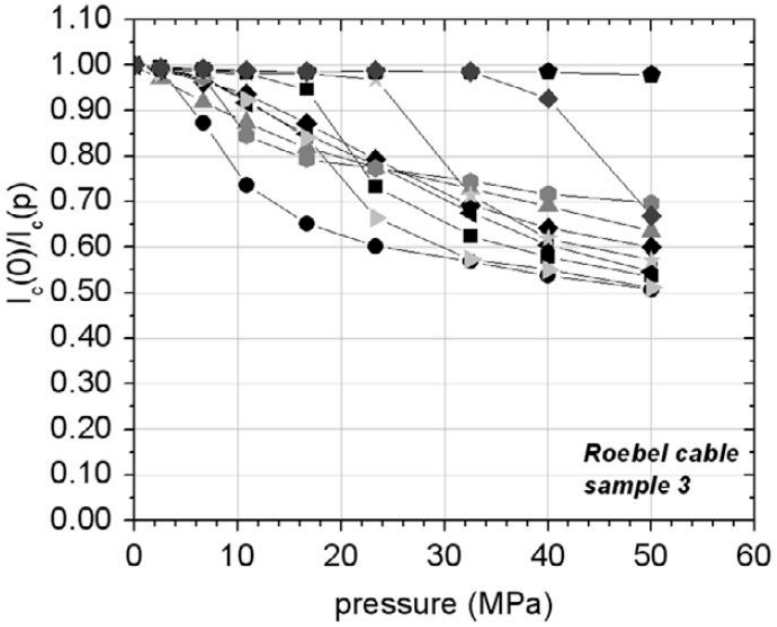
C. Barth *et al.,* Supercond. Sci. Technol. 25 (2012) 025007 (9pp)

Outline

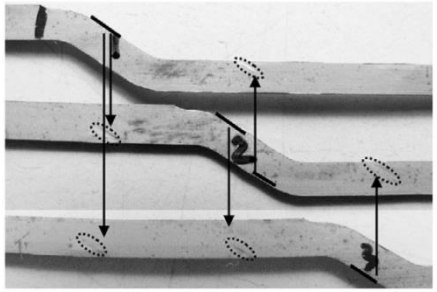

Bending properties
Tensile stress
Transversal stress
Impregnation

Different compressive stress values 10 – 40 MPa

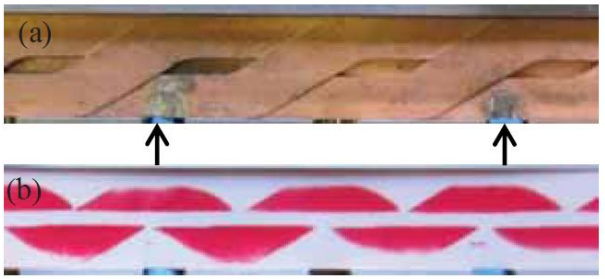
D. Uglietti et *al.*, Supercond. Sci. Technol. 26 (2013) 074002 (5pp)



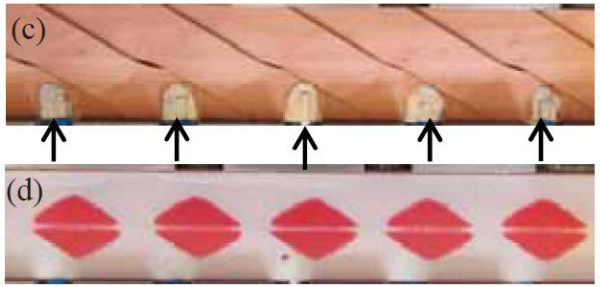
- degradation of the individual strands I_c by 30% at a transverse stress of 10 MPa.



J. Fleiter et *al.*, Supercond. Sci. Technol. 26 (2013) 065014 (5pp)

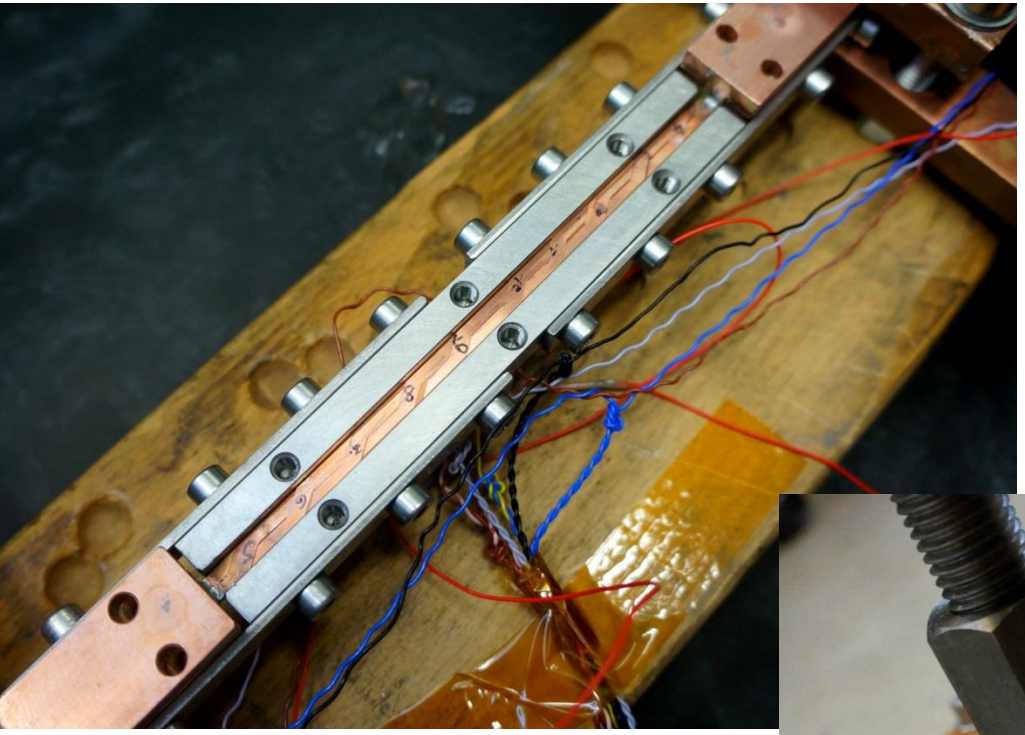


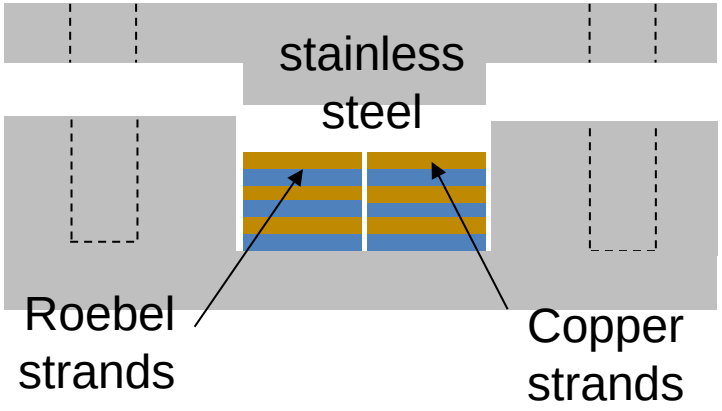
- GCS cable: 15 strands, TL: 300 mm
- Effective stress: 111 MPa (36% surface)

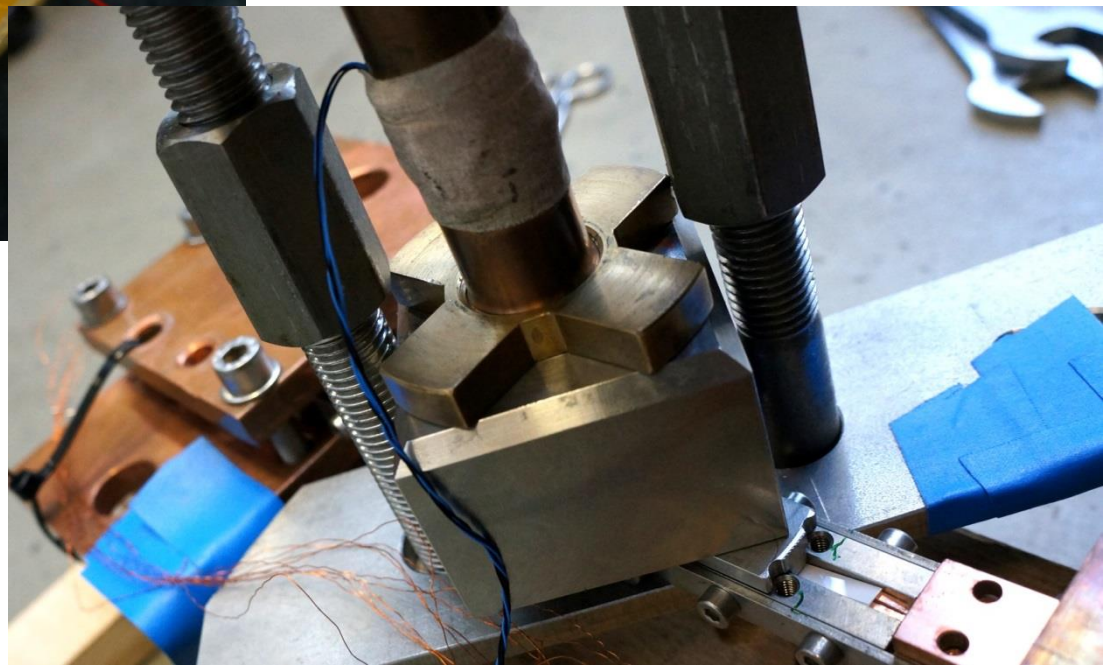


- KIT cable: 10 strands, TL: 126 mm
- Effective stress: 167 MPa (24% surface)

Transversal stress test with additional copper strands

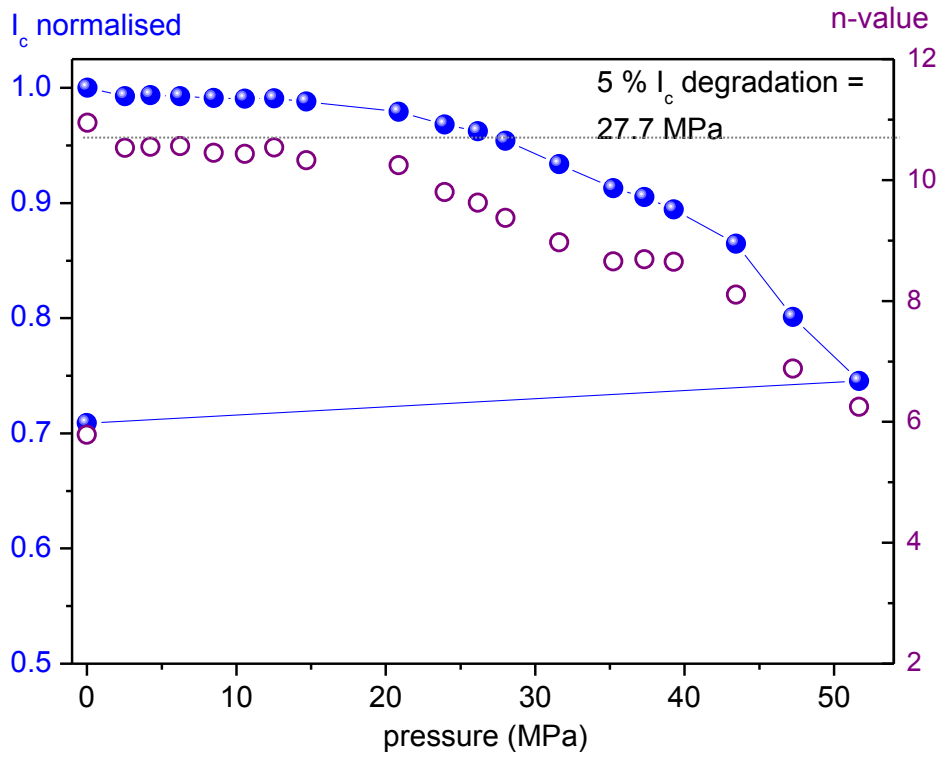


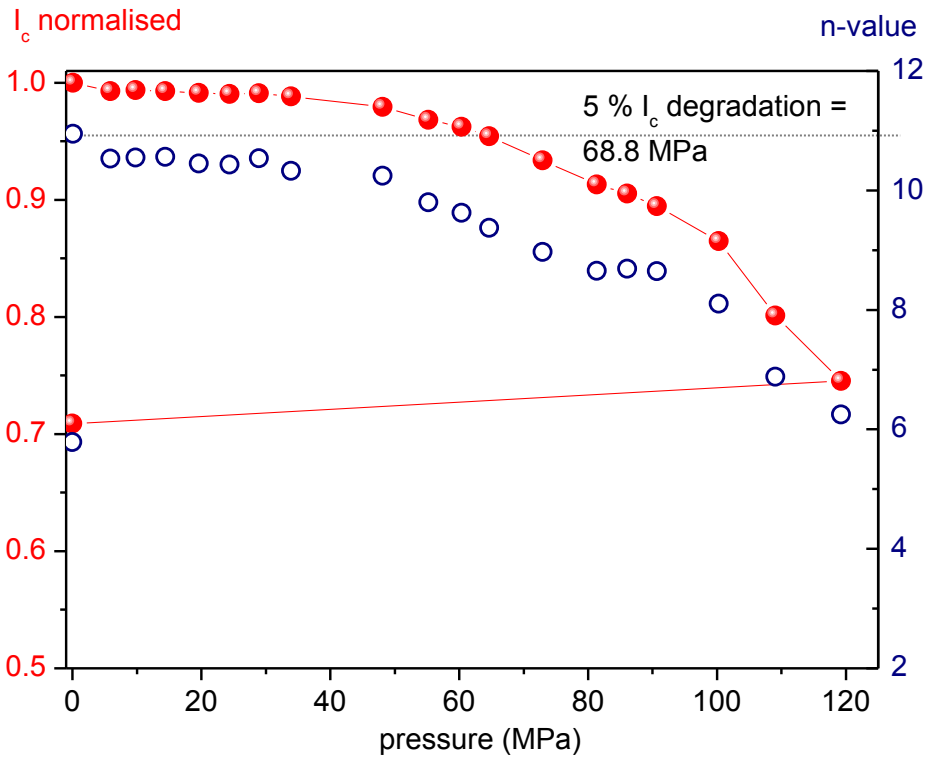




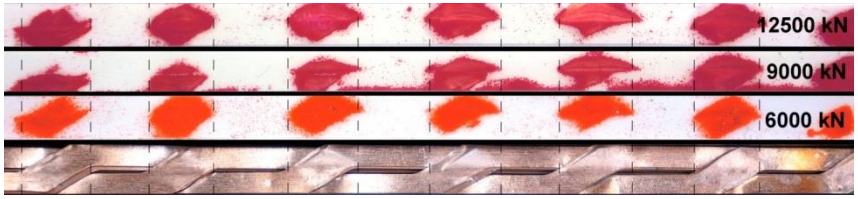
- Contact area of stainless steel: 4 mm x 85 mm

5% I_c degradation by 68.8 MPa effective stress





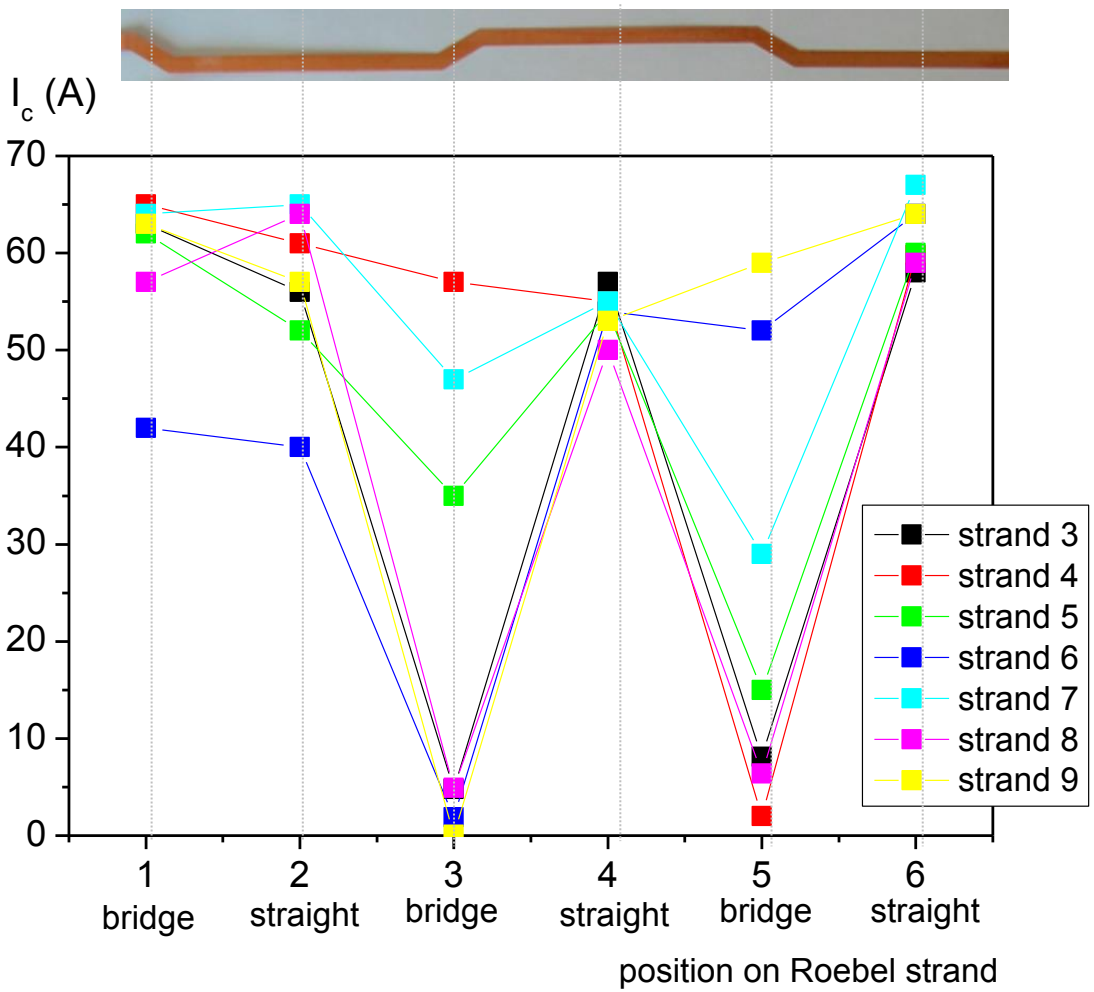
- Average transverse stress (cable surface)



- Effective transverse stress

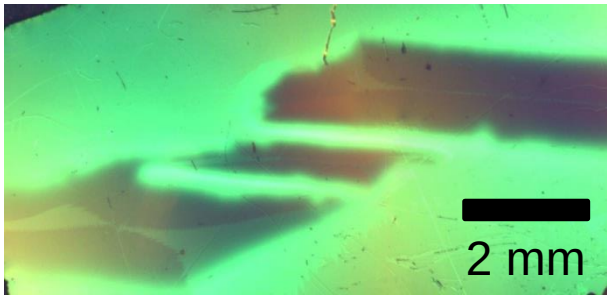
To be published

Defects on the Roebel-bridge



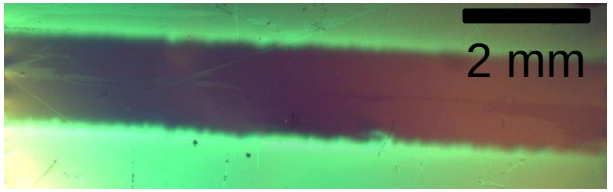
- I_c measurements after deassembly of the Roebel cable

Magneto-optical Imaging



60 K, 20 mT

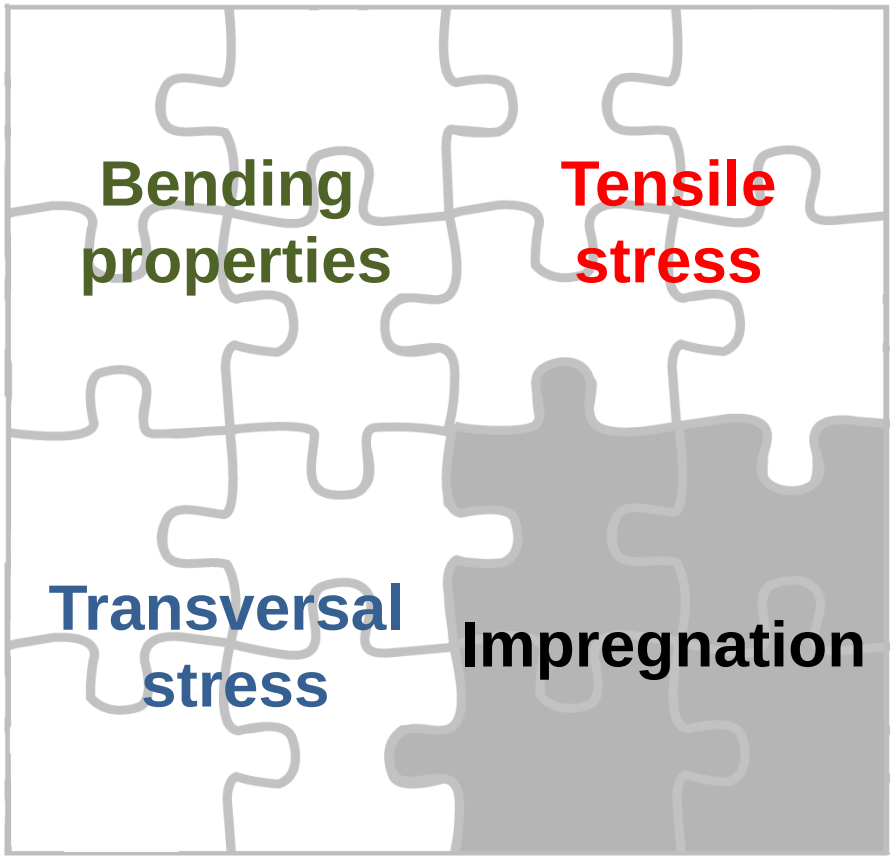
61 K, 30 mT



60 K, 25 mT

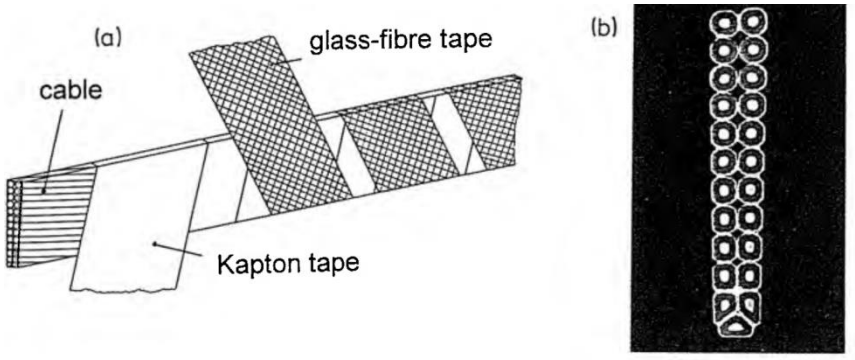
To be published

Outline


Bending properties
Tensile stress
Transversal stress
Impregnation

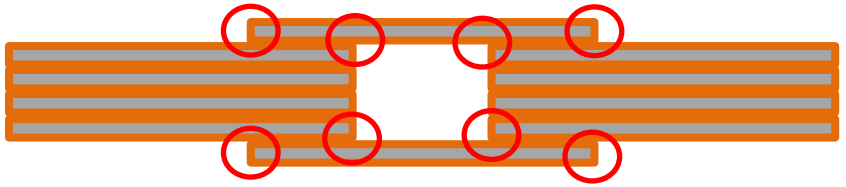
Epoxy choice

- Commercially available resins with fillers
- Thermal expansion
- Thermal conductivity
- Chemical compatibility with *RE*BCO
- Resin working temperature
- Resin viscosity



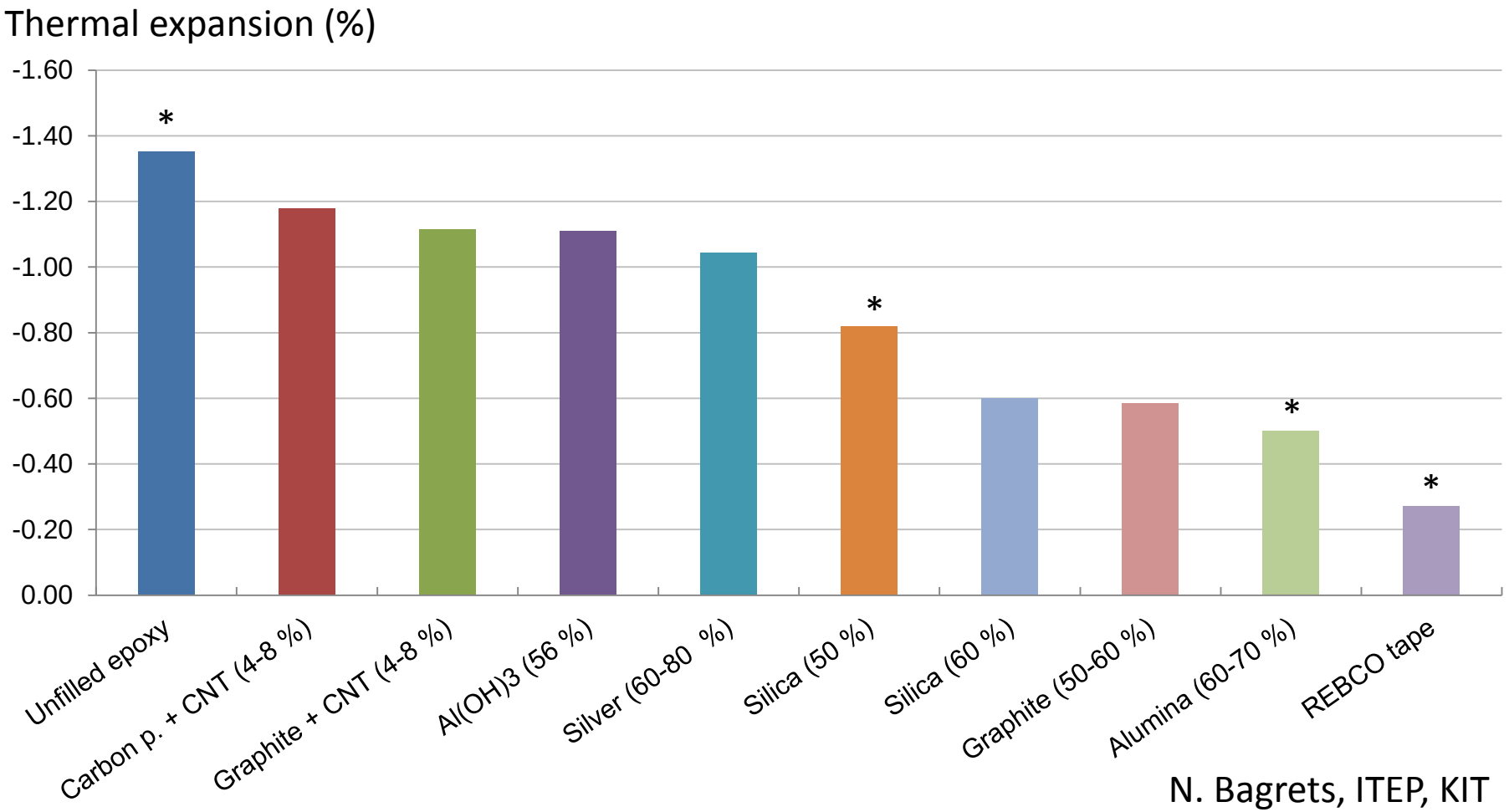
Low T_c cable example

Fred M. Asner, High Field Superconducting Magnets, CLARENDON PRESS OXFORD 1999



Stress concentrations

Thermal expansion similar to *RE*BCO for more then 50% filled epoxy's



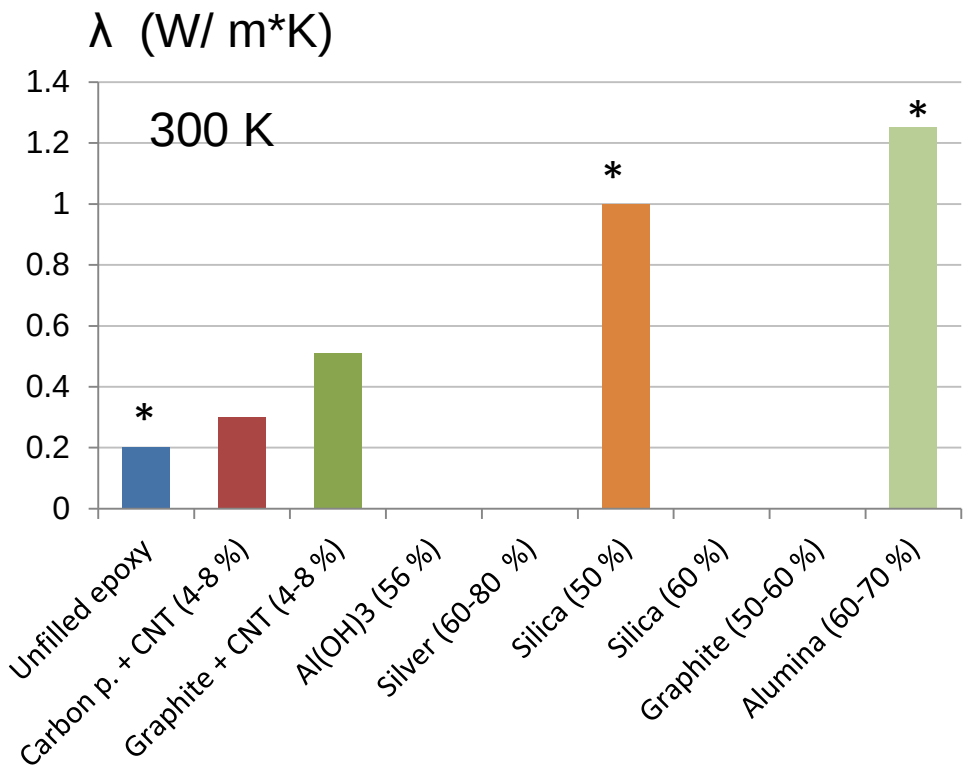
N. Bagrets, ITEP, KIT

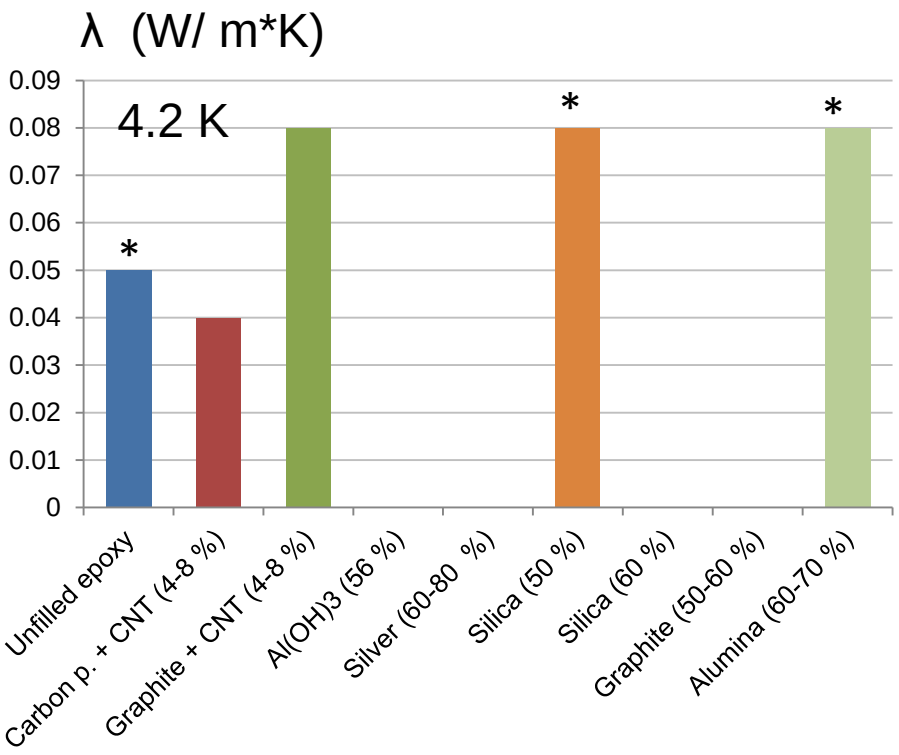
- Thermal expansion < 0.7 % preferred

To be published

* C. Barth,PhD thesis (2013)

Equal thermal conductivity at 4.2 K for silica and alumina filled epoxy's





S. Drotziger, ITEP, KIT

- At 4.2 K, all epoxies have very low thermal conductivity
- Effect of fillers is small compared to 77-300 K

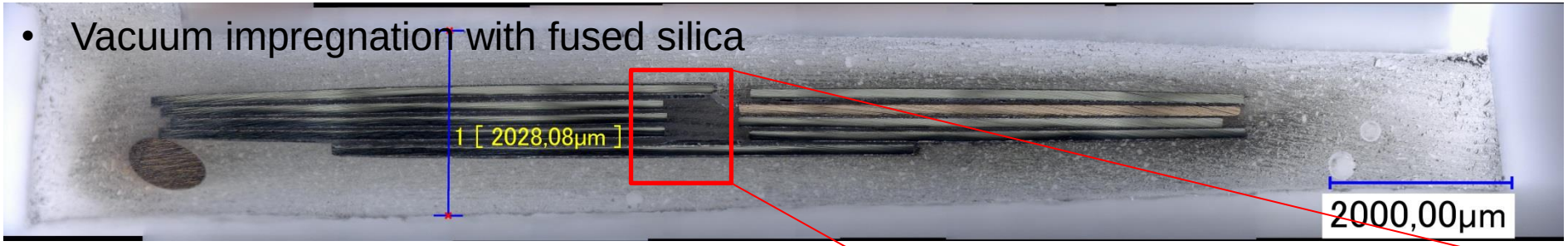
To be published

* C. Barth, PhD thesis (2013)

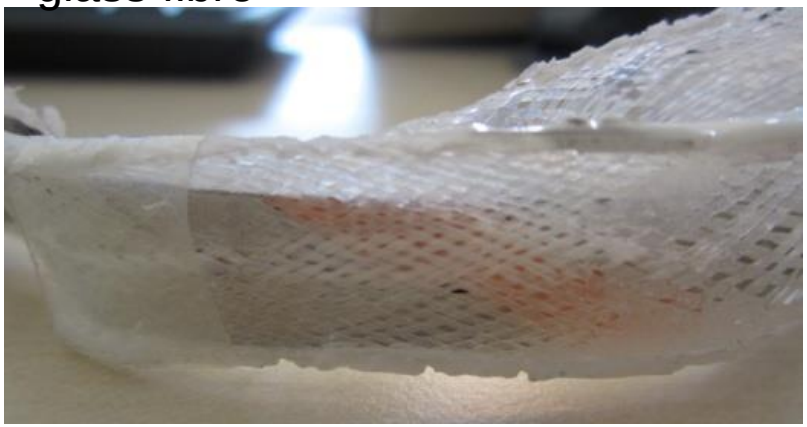
Impregnation of dummy Roebel cables

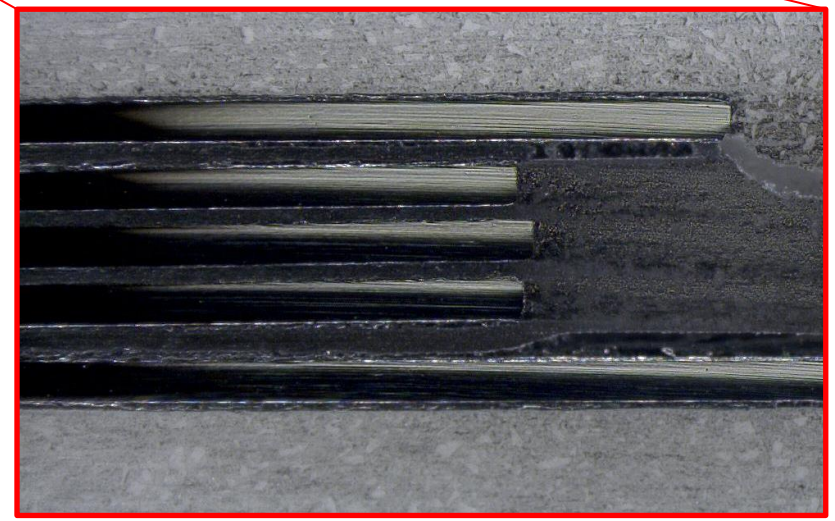
- Wet-winding

- Vacuum impregnation with fused silica



- Vacuum impregnation with fused silica and glass fibre

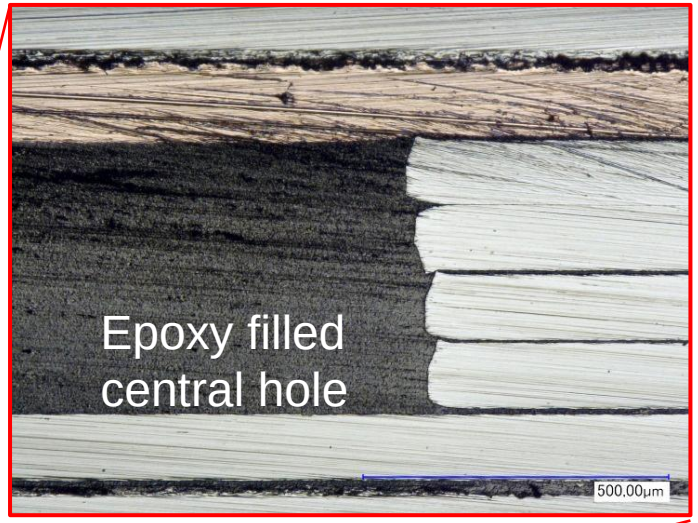


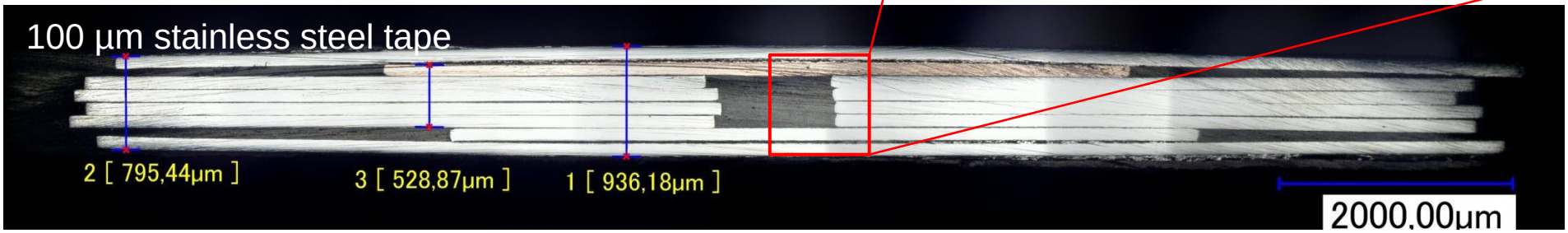


To be published

Vacuum impregnation with Araldite and 50% fused silica

- Dummy between two stainless steel tapes
- Araldite CY5538/HY5571 with 50 wt% fused silica
- T = 80 °C, P = 0.3 kPa
- Thickness < 1 mm → high current density





- Dummy with one SP *RE*BCO strand
- I_c measurement at 77 K
- No I_c degradation

	I_c [A]	n
Before impregnation	171.7	28.1
After impregnation	170.2	26.8
After impregnation 2x	170.9	28.5

To be published

Transverse pressure tests (U. Twente)

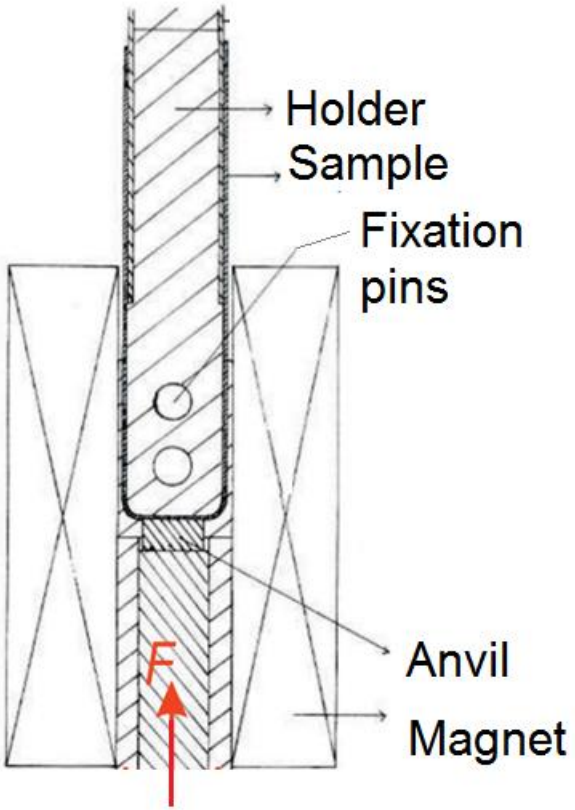
Samples to be tested

- Reference cable
- Impregnated cable

  (CY5538/HY5571 + 50 wt% silica)

Cryogenic press (UTwente)

- T = 4.2 K
- I_{max} = 50 kA
- B_{max} = 11 T (perpendicular)
- F_{max} = 260 kN
- U-shaped samples



W. Van de Camp, master thesis, University of Twente, 2012

Summary

Karlsruhe Institute of Technology

Bending

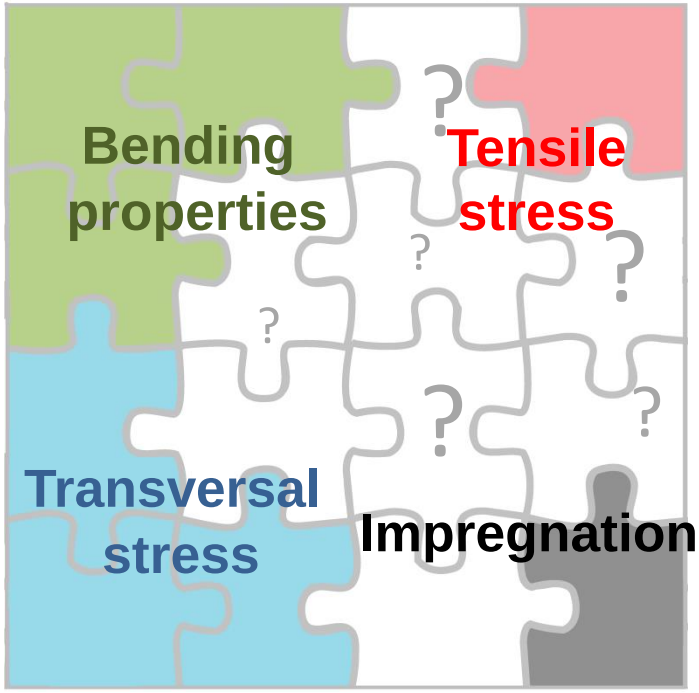
- Easy direction down to 10 mm radius: TL:126 mm, 10 strands cable
- Depends on: TL, no. of tapes, SC tape

Tensile stress

- Optimised structure: outer corner, inner radius 10 mm (fixed)

Transverse stress

- Impregnation support needed



Impregnation

- Vacuum impregnation with Araldite 50% fused silica proposed