Poster M2Po2C-01 [37]

UNIVERSITY OF TWENTE. EMS

Pressure-induced critical current reduction in impregnated Nb_3Sn Rutherford cables for use in future accelerator magnets

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Objective:

Study of the deviatoric strain in the strands of a Nb_3Sn Rutherford cable using 2D FE mechanical models, to:

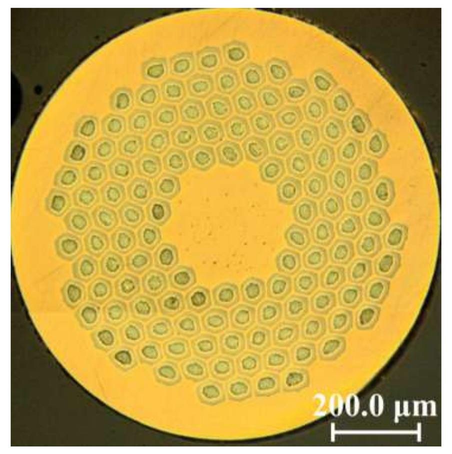
- Understand the influence of the **epoxy** and **glass** properties;
- Understand the influence of the **confinement geometry**.

Strand and Cables:

- Strand Sample:

  Bruker OST RRP-132/169, diameter 1.0 mm, filament size 58 µm, Cu / non-Cu ratio 1.22;
- Cable Sample:

  18 strands of Ø 1.0 mm , rectangular size 9.97 mm x 1.81 mm, twist pitch 63 mm;
- Cables developed for the 16 T Nb_3Sn Short Model Coil (SMC) demonstrator magnets at CERN.

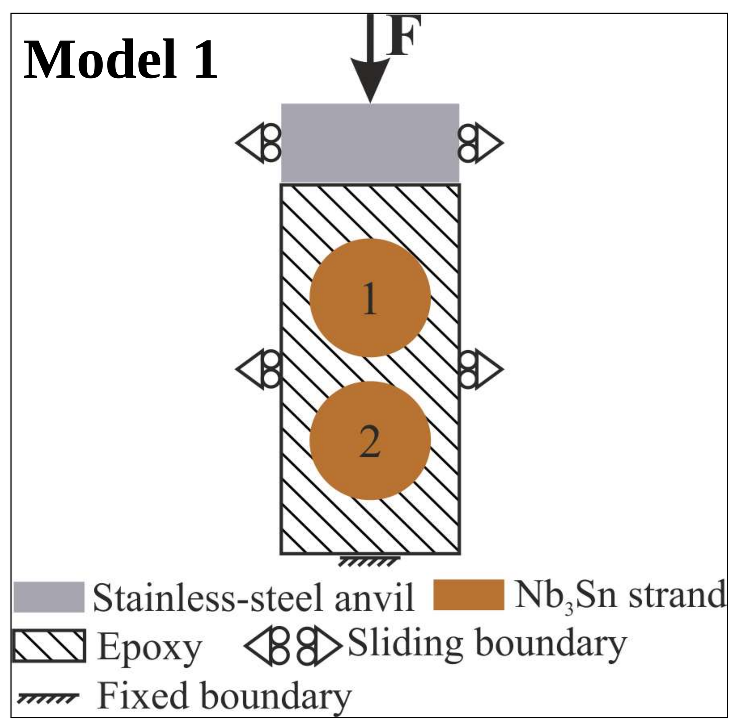


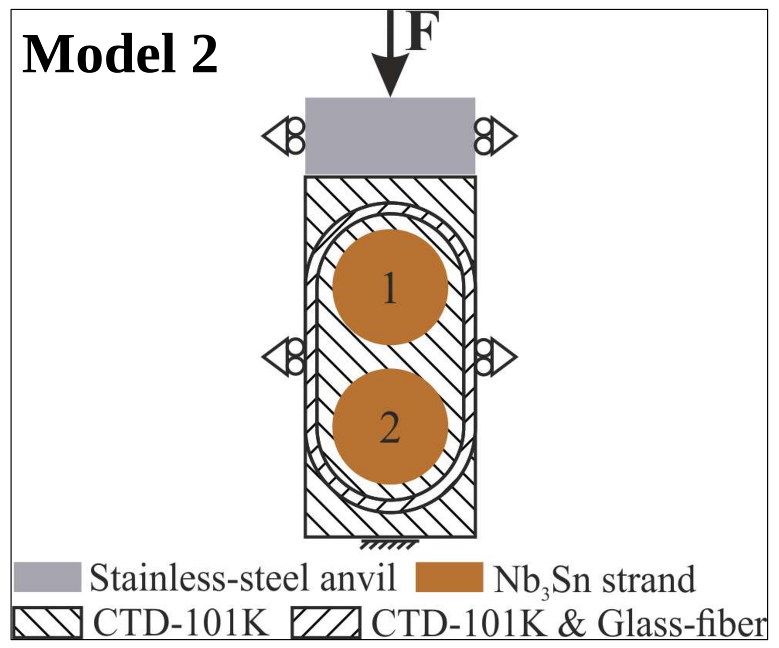
Bruker OST RRP-132/169

'U'-shape sample test:

Cable test facility at University of Twente

2-Strand Models 1 & 2:

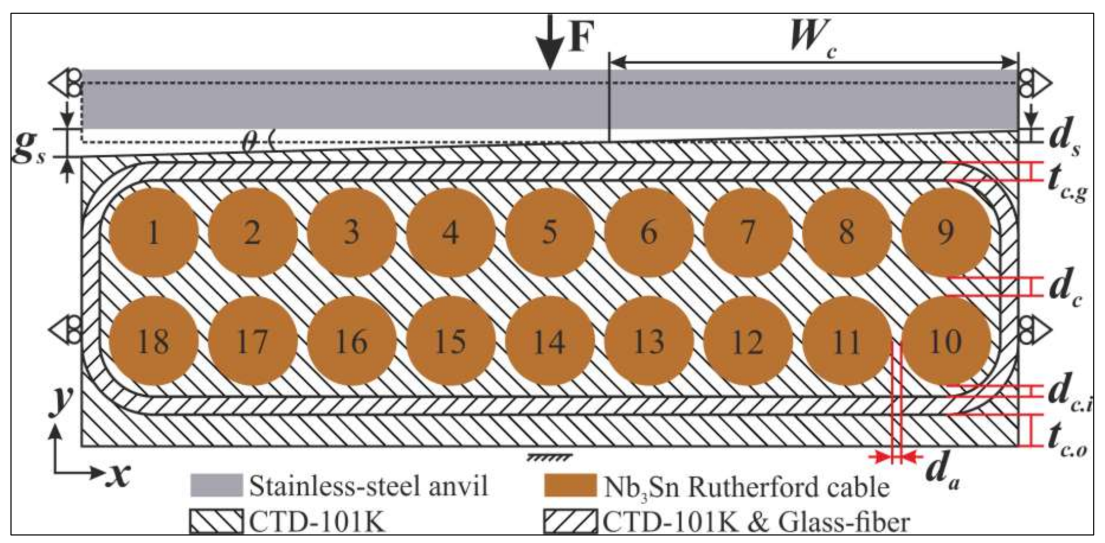


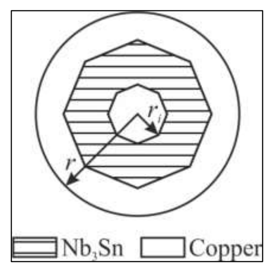


- P = 100 MPa;
- Pressurized area section: 1.2 mm × 46 mm

T = 4.2 K	E (GPa)	v
Nb_3Sn	75	0.36
Epoxy	1 to 40	0.1 to 0.4
Stainless steel 316L	207	0.284

Model 3: cable with a misalignment angle θ





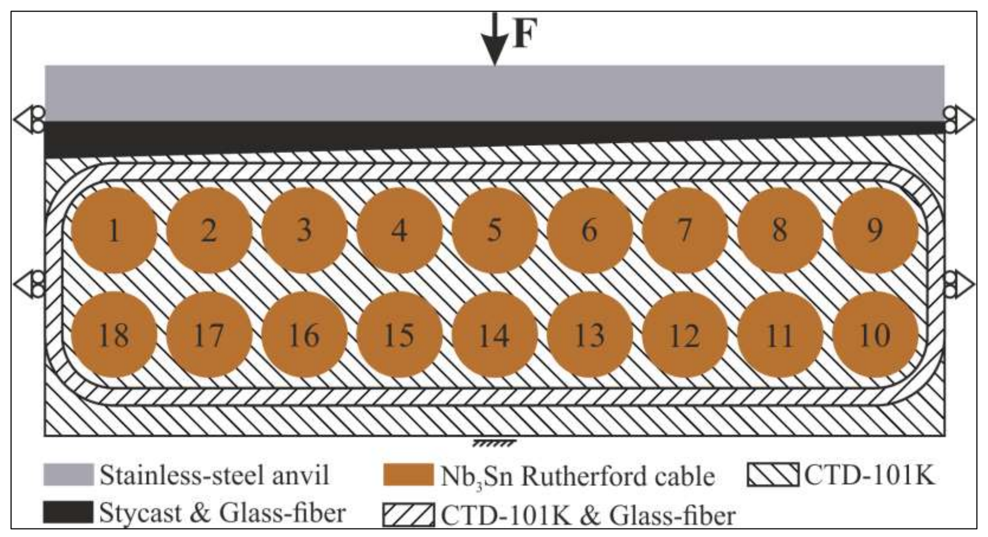
F = 20 kN;

r_i = 200 µm;

r = 1.0 mm

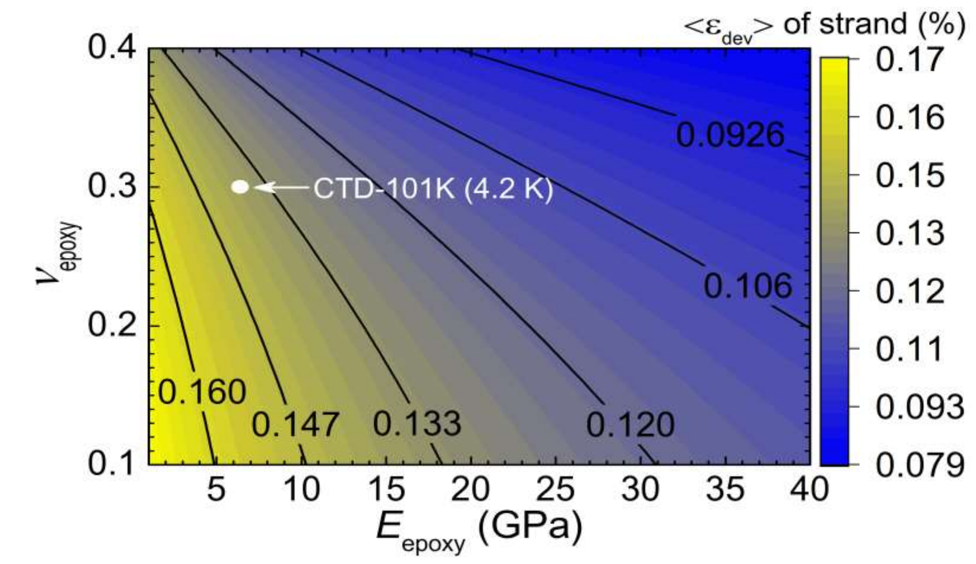
Parameter	Description	Unit	Value
r	Radius of the strand	mm	0.5
$t_{c.o}$	Thickness of the outer CTD-101K	mm	0.1
$t_{c.g}$	Thickness of CTD-101K & glass-fiber	µm	50
$d_{c.i}$	Distance between strand and glass-fiber	µm	50
d_a	Distance between neighboring strands in the same layer	µm	50
d_c	Distance between neighboring strands in different layers	mm	0.1

Model 4: effect of the 'alignment' impregnation

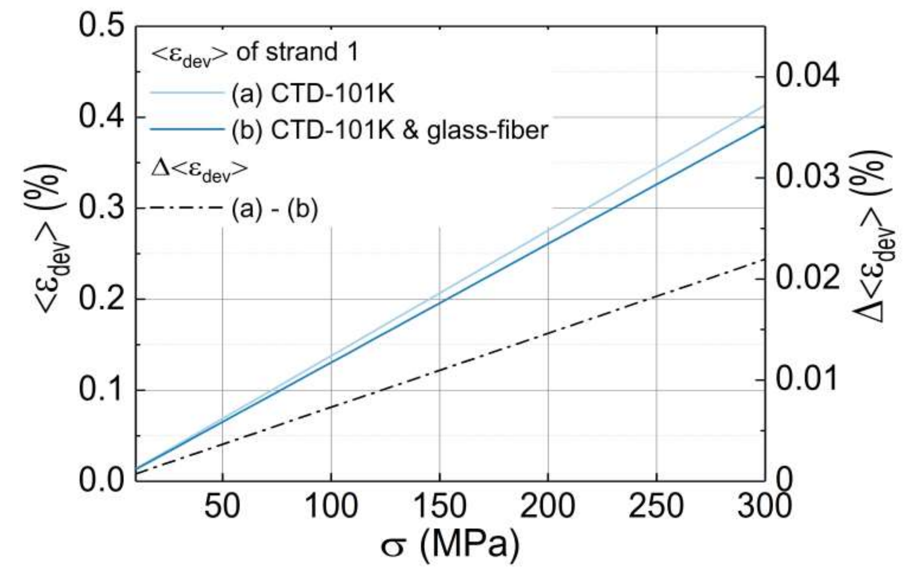


Used Young's modulus and Poisson's ratio of STYCAST 2850FT / 23LV: E = 30 GPa, v = 0.1 & 0.4.

Result 1:

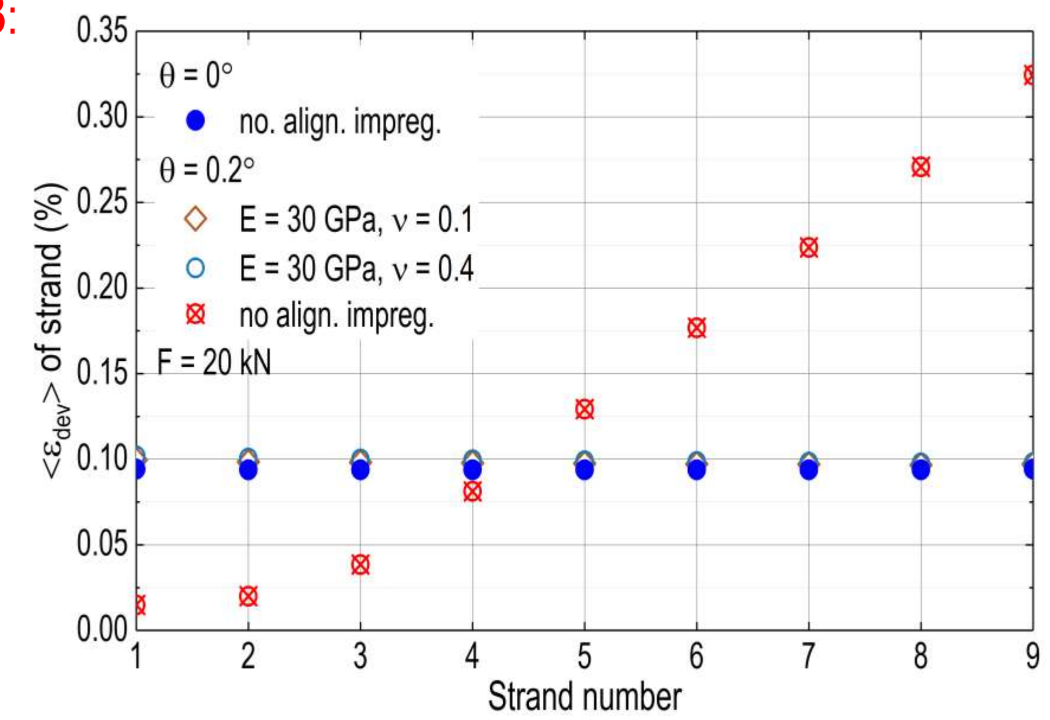


Result 2:

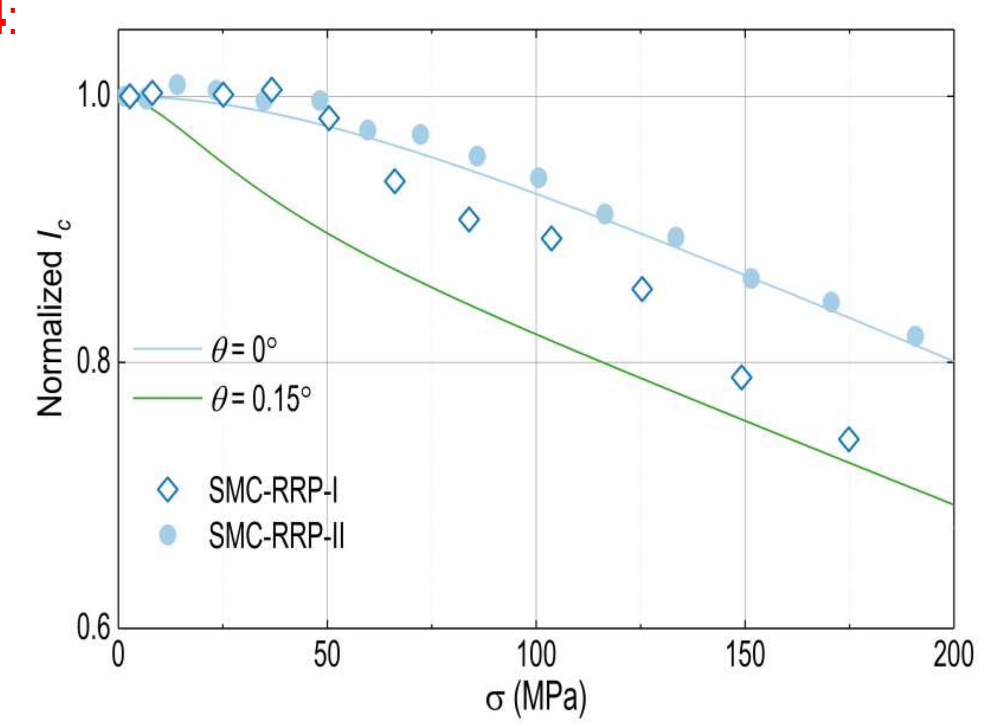


- The average deviatoric strain in strands in Nb_3Sn Rutherford cables decreases with increasing E_{epoxy}, as the epoxy resin increasingly carries part of the transverse load;
- An increasing Poisson's ratio v_{epoxy}, and therefore an increasing bulk modulus $k_{epoxy} = E_{epoxy} / 3(1-2v_{epoxy})$, renders the stress in the strand more hydrostatic and thus also reduces the deviatoric strain component;
- Cable impregnation with CTD-101/glass-fiber mixture, causes a 5% lower average deviatoric strain than with pure CTD-101K!

Result 3:



Result 4:



- $\langle\varepsilon_{dev}\rangle$ of strand 9 (θ=0.2°) is 3 to 3.5 times higher than in the 'perfect' experiment (θ=0°) when no 'alignment' impregnation is applied.
- A small misalignment angle of 0.15° already causes a 13% lower critical current at a transverse pressure of 200 MPa compared to the 'perfect' aligned case.
- With the 'alignment' impregnation, the effect of the misalignment angle is eliminated and the variation of the deviatoric strain in strands is reduced to less than 1%, which $\langle\varepsilon_{dev}\rangle$ value is nearly identical to the one found for θ = 0°.

Conclusion:

- Since the deviatoric strain in Nb_3Sn filaments has a direct impact on the critical current density, the use of a stiff and relatively incompressible epoxy resin significantly improves the pressure tolerance of cables.
- The mechanical effect of an insulating glass sleeve around the cable is relatively small.
- A misalignment angle as small as 0.2° between pressure block and cable surface causes a strain concentration by some factor 3 in the strands at the side of the cable that comes into contact with the anvil first.
- **It should be noted that similar imperfections leading to stress- and strain concentrations may well occur also in the winding pack of real magnets, which our experiment is designed to mimic.**
- The corrective alignment impregnation significantly improves the strain homogeneity in the transverse press experiments, rendering it essentially equal to the strain modelled for the perfectly aligned situation.