Characterization of the stress distribution on Nb_3Sn Rutherford cables under transverse compression

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1. Background

The coils of high field Nb_3Sn magnets are submitted to large loads during assembly at ambient temperature and during operation at cold. This study addresses the characterization of the stress distribution on reacted and impregnated Nb_3Sn Rutherford cables under transverse compression, at ambient temperature, in a similar configuration as seen during magnet assembly. We performed an experimental campaign on different type of samples to measure the local stress distribution on the contact surface of the impregnated cable.

2. Objectives

- Apply a uniform compressive load on a cable.
- Identify the stress distribution on the cable surface.
- Characterize the stress state inside the strand.

6. Conclusion

- A uniform compressive load on a double stack can be applied.
- The applied stress distribution can be precisely analysed with Prescale film.
- Crack propagation in the resin started to become visible at 150 MPa.
- Over 175 MPa the irreversible critical current degradation was observed.
- A linear elastic FEM model of a real cable shape based on a X-ray tomography, which can be used to identify the stress concentration in the strand, was implemented.

3. Test routine

Extract cable from FRESCA sample holder
- 1800 mm stress sensitive Nb_3Sn cable

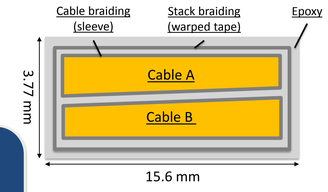
Transport to press system
- $\sigma_z \ll 50$ MPa

Insert in pressing tool and perform press cycle
- Uniform stress distribution
- Low stress peaks
- Load steps of 50, 100, 125, 150, 175 , 200 and 230 MPa

Perform I_c measurement in FRESCA

Transport to FRESCA
- Low tensile stress in the cable, $\sigma_z \ll 50$ MPa

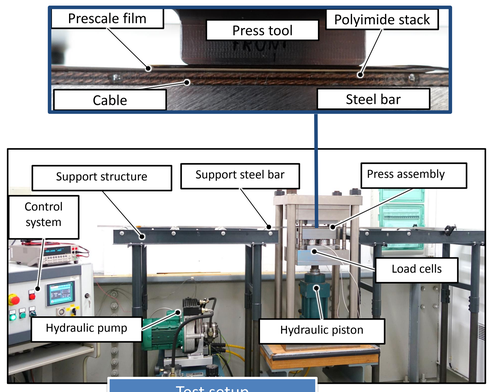
Re-fit in FRESCA sample holder
- Permanent cable support against bending



Production No.	HT15OC0190
Virgin strand I_c (4.2K,12T)	438 A
Number of strands	40
Strand type	144/169 RRP
Strand diameter	0.07
Bare width	14.7
Bare mid thickness	1.25
Keystone angle	0.79°
Epoxy	CTD-101K
Insulation	S2-Glass (0.1 mm tape, 0.15 mm sleeve)

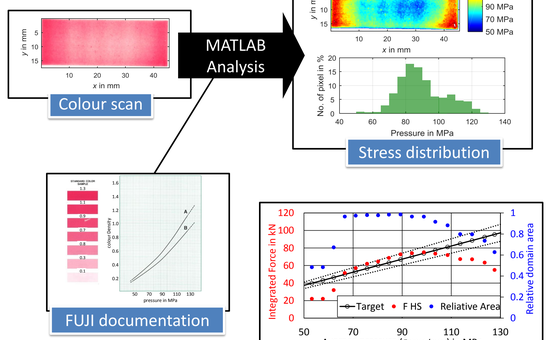
4. Methods

Press system

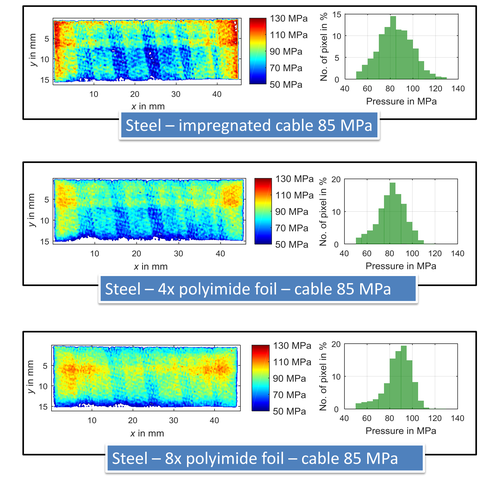


Test setup

Compressive stress evaluation up to 230 MPa



Stress uniformity



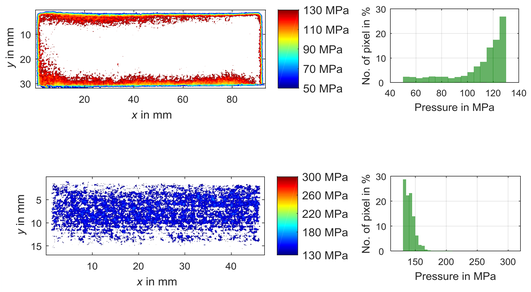
5. Results

$$F_{PS} = \sum_{i=1}^{n} c(\sigma_i)\,\sigma_i\,A_P \quad \text{... Force Prescale films}$$

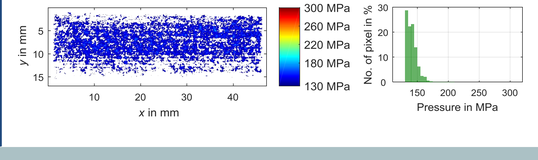
$$F_{LC} = \sum_{i=1}^{4} F_{LC_i} \quad \text{... Force load cells}$$

150 MPa

F_{LC} = 103.6 kN
F_{PS} = 66.1 kN



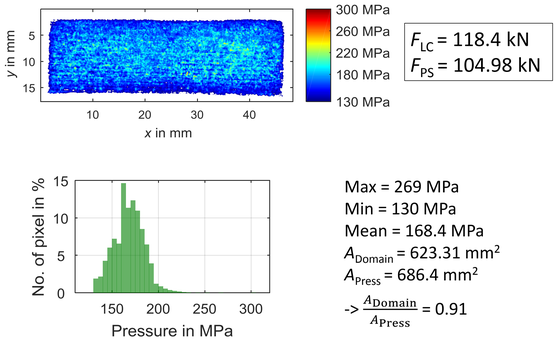
$F_{PS\,HS}$ = 20.8 kN
Max = 130 MPa
Min = 50 MPa
Mean = 110.1 MPa
A_{Domain} = 188.7 mm²
A_{Press} = 686.4 mm²
-> $\frac{A_{Domain}}{A_{Press}}$ = 0.275



$F_{PS\,HHS}$ = 45.3 kN
Max = 207.3 MPa
Min = 130 MPa
Mean = 140.9 MPa
A_{Domain} = 321.3 mm²
A_{Press} = 686.4 mm²
-> $\frac{A_{Domain}}{A_{Press}}$ = 0.47

175 MPa

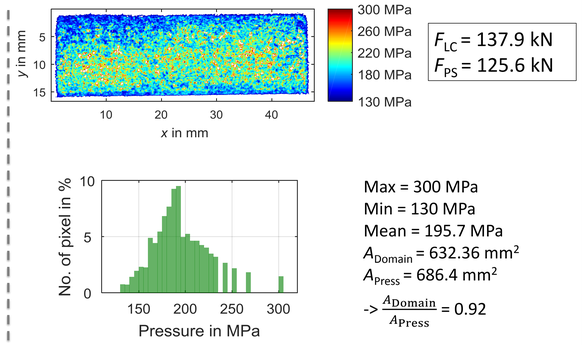
F_{LC} = 118.4 kN
F_{PS} = 104.98 kN



Max = 269 MPa
Min = 130 MPa
Mean = 168.4 MPa
A_{Domain} = 623.31 mm²
A_{Press} = 686.4 mm²
-> $\frac{A_{Domain}}{A_{Press}}$ = 0.91

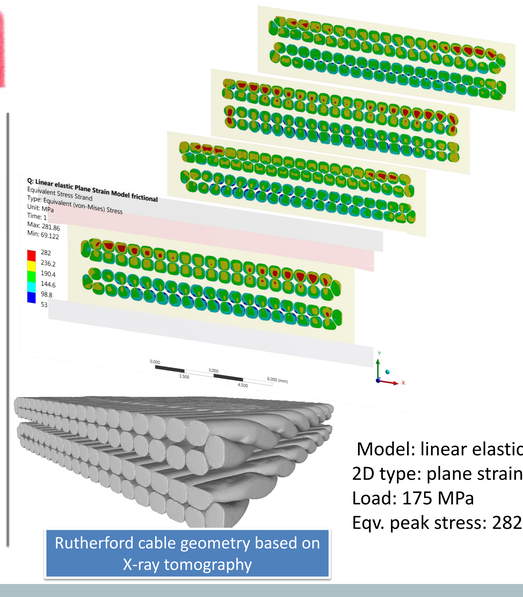
200 MPa

F_{LC} = 137.9 kN
F_{PS} = 125.6 kN



Max = 300 MPa
Min = 130 MPa
Mean = 195.7 MPa
A_{Domain} = 632.36 mm²
A_{Press} = 686.4 mm²
-> $\frac{A_{Domain}}{A_{Press}}$ = 0.92

FEM based on tomography



Rutherford cable geometry based on X-ray tomography

Model: linear elastic
2D type: plane strain
Load: 175 MPa
Eqv. peak stress: 282 MPa

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