EPFL

Bruker Nb_3Sn Strands under Bending Strains

J. Greenwood,
M. Barbagallo,
and
P. Bruzzone

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SWISS PLASMA CENTER

Motivation

To understand the tolerance of the Bruker strands to bending strain after reaction

Method

1. React strands on steel cylinders with different radii

2. Transfer reacted strands to ITER barrels, that have an outer radius of ~15 mm.

3. Measure I_C

Strand Selection and Heat Treatment

Samples have been taken from spool **H0049-4.**

- Strand Cu:non-Cu ratio ~1.19*
- RRR likely to be 50-100*
- Twist pitch 15 ± 2 mm*
- Diameter 0.697 mm

The samples were wound onto the steel cylinders and then heat treated in a vacuum furnace as follows:

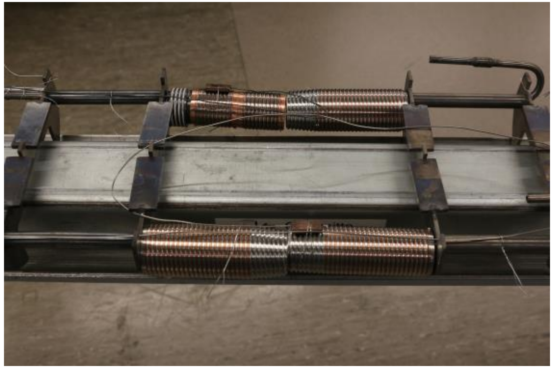
210ºC for 48 hours

↓

400ºC for 48 hours

↓

650ºC for 50 hours



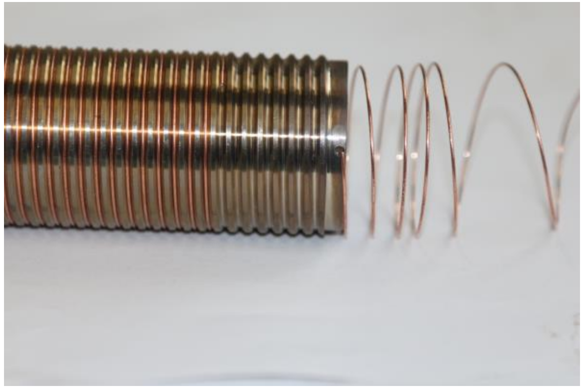
*Taken from the customer product sheet. Bruker have not provided spool specific data.

Issue Encountered After Heat Treatment

The strands were removed from the furnace on Friday 5th April.

Unfortunately the strands are strongly bonded to steel barrels, probably because the barrels were not heat treated before the strands were mounted.

New strands are now being wound onto the barrels.



There will be a distribution of bending strain through the thickness of the strand. The largest strain values are given by [1]:

$$\varepsilon_B(R_{HT}) = \pm\frac{t}{2}\left(\frac{1}{R_B} - \frac{1}{R_{HT}}\right)$$

ε_B	**Heat Treatment Radius**
± 0.1458%	16 mm
± 0.2745%	17 mm
± 0.3888%	18 mm
± 0.4912%	19 mm

ε_B = bending strain

$t = 0.7$ mm (strand diameter)*

$R_B = 15$ mm (ITER barrel radius)

R_{HT} = heat treatment cylinder radius

[1] See, e.g., G. Ambrosio *et al.*, *Study of the React and Wind Technique for a Nb3Sn Common Dipole* IEEE TAS **10**:1 (2000)

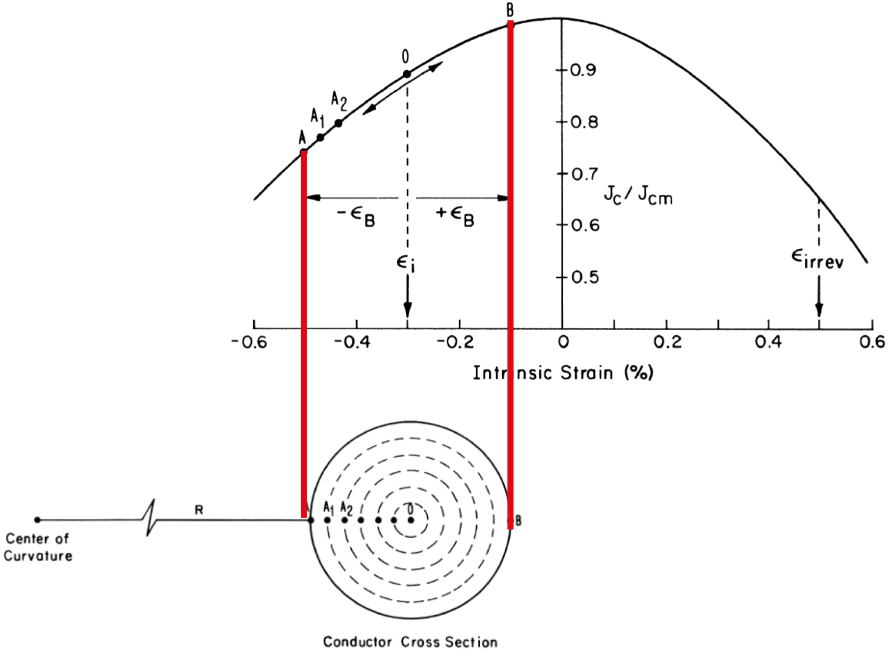
* Filamentary zone diameter is ~0.45 mm

Extra: Distributions of Bending Strain

Distributions of bending strain will lead to distributions of J_C in the strand.

For strands where the interfilamentary current transfer length L is much shorter than the filament twist pitch l (which is *usually* a valid assumption* for Nb_3Sn), one can calculate the strand's I_C using**:

$$\frac{I_c}{I_{cm}} = \frac{2}{\pi \varepsilon_B^2} \int_{-\varepsilon_B}^{\varepsilon_B} (\varepsilon_B^2 - x^2)^{1/2} \frac{J_c(\varepsilon_i + x)}{J_{cm}} dx$$



*The *assumption* is valid if the Cu matrix RRR is reasonably high
**The equation requires knowledge of the axial strain behaviour.

[1] J. W. Ekin, *Strain Scaling Law and the Prediction of Uniaxial and Bending Strain Effects in Multiflimentary Superconductors*, Filamentary A15 Superconductors (Suenaga & Clark) 1980, p187-203