

Nb₃Sn cable modelling

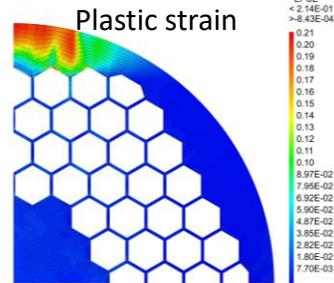
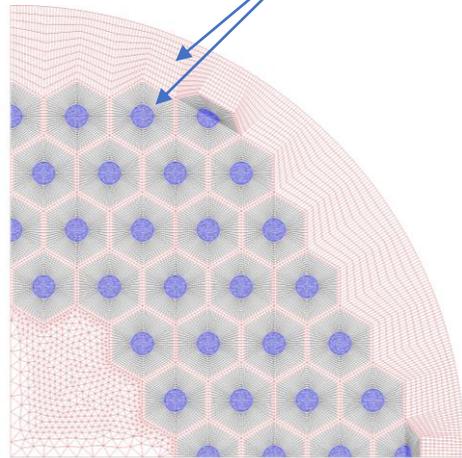
CG, 26/07/2023

Model

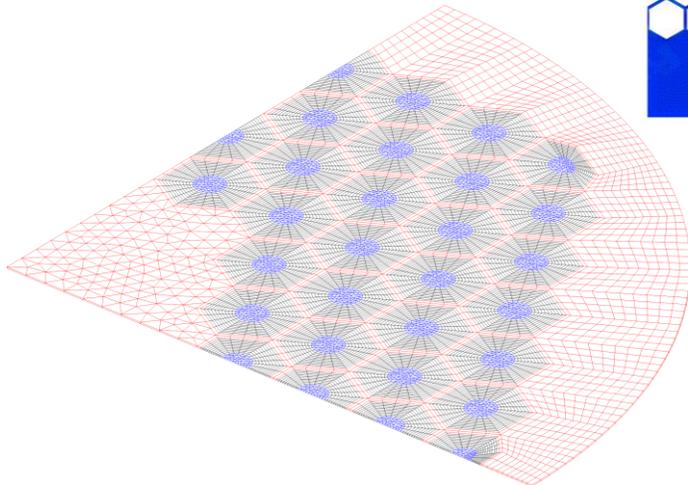
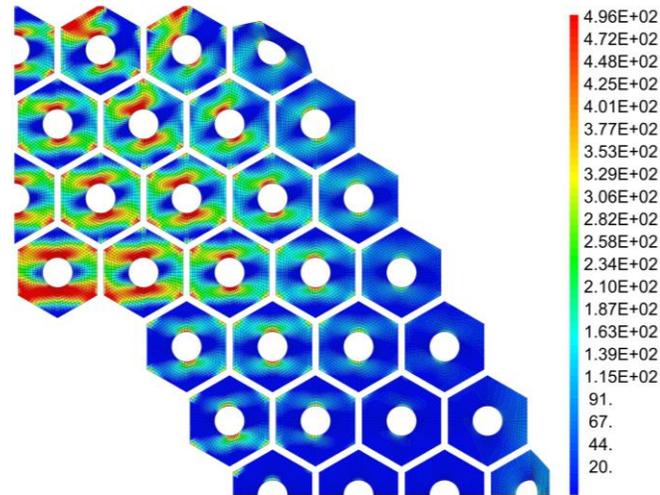
Experimental activities

Microscopic and equivalent wire models

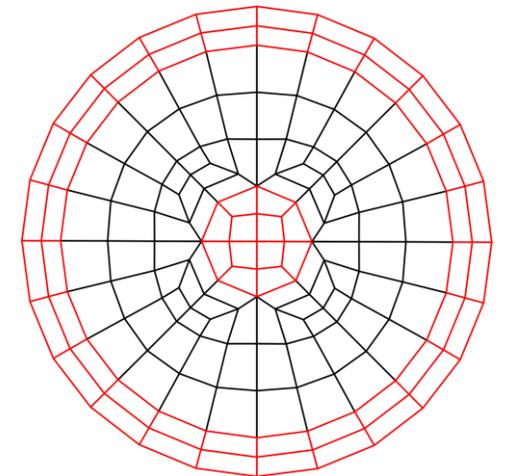
“Simple” elastic-plastic model



Principal stress [Mpa]

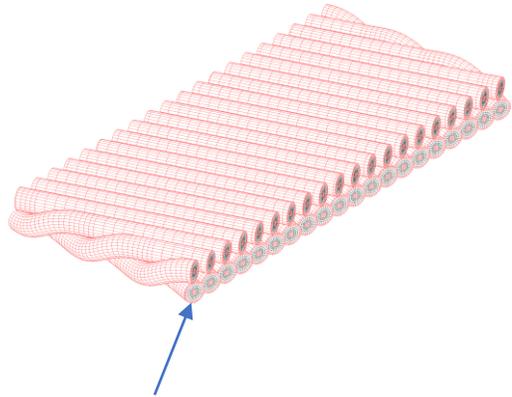


Equivalent wire



Microscopic and equivalent wire models

Mesoscopic cable model

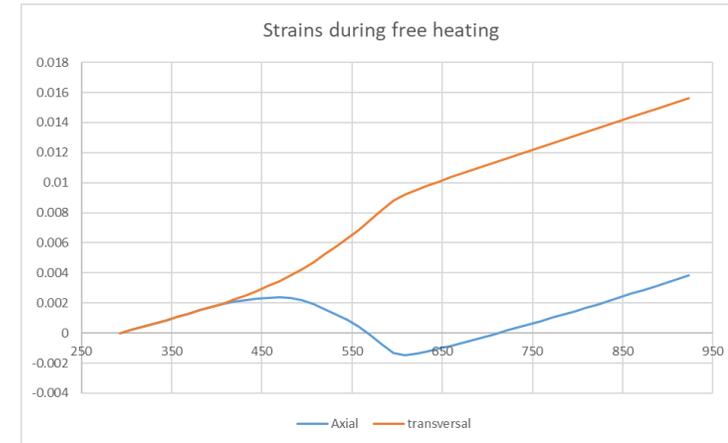
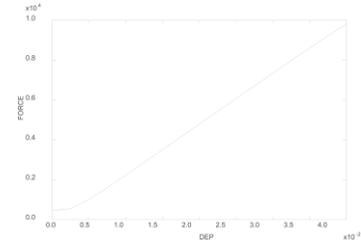
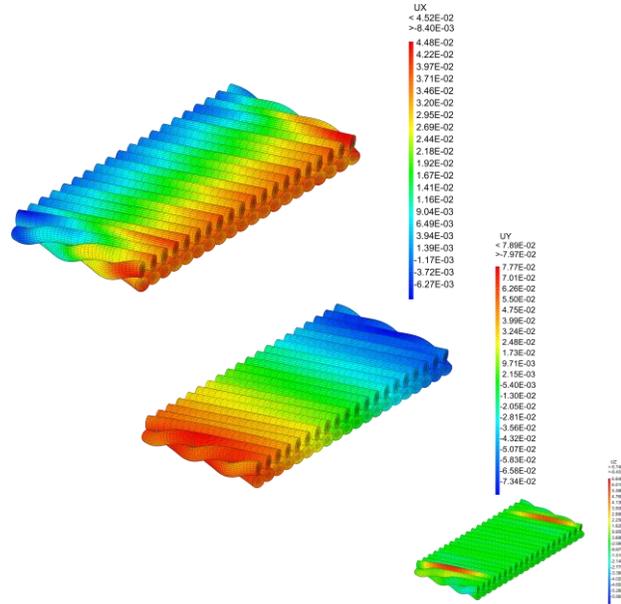


Equivalent wire

St. St foil to be added



Macroscopic equivalent cable model



Model with initial back stress

The constitutive model shall be coherent with the FEA code expected to be used.

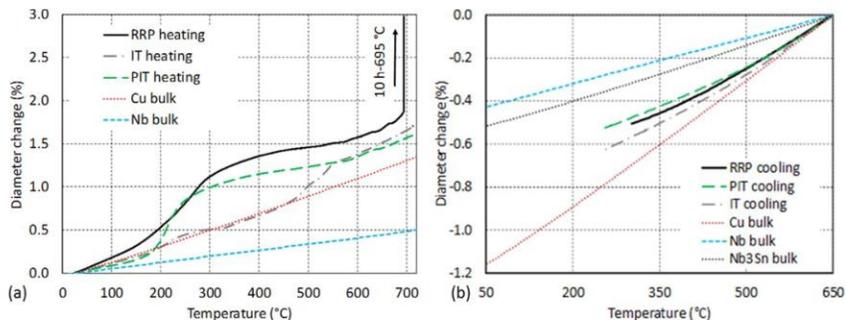


Figure 1. (a) Typical evolution of the RRP, PIT and IT wire diameters as measured by dilation during RHT with a ramp rate of $1.67 \text{ }^\circ\text{C min}^{-1}$. (b) Evolution of the reacted RRP, PIT and IT wire diameters during cooling from $650 \text{ }^\circ\text{C}$ (average of at least two independent measurements). The thermal expansions of Cu, Nb and Nb_3Sn are shown for comparison.

Table 1. Comparison of Nb_3Sn wire diameter and wire and cable length changes before and after RHT. The change to the wire's cross-sectional area was calculated from the diameter change.

	Wire			Cable [11]
	Diameter change (%)	Cross-sectional area change (%)	Length change (%)	Length change (%)
RRP	+2.5	+4.9	-0.07	-0.32
PIT	+1.6	+3.3	-0.15	-0.40
IT	+1.1	+2.3	not measured	not measured

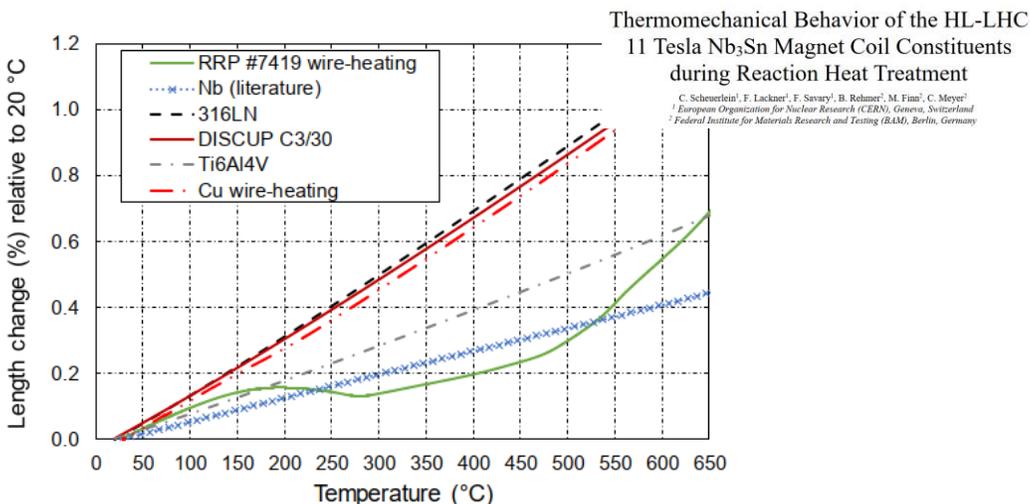


Fig. 10: Comparison of RRP #7419 Nb_3Sn wire axial length change during first heating with that of DISCUS C3/30, Ti6Al4V, and 316LN. The relative length changes of a Cu wire and the Nb thermal expansion from reference [20] are shown for comparison.

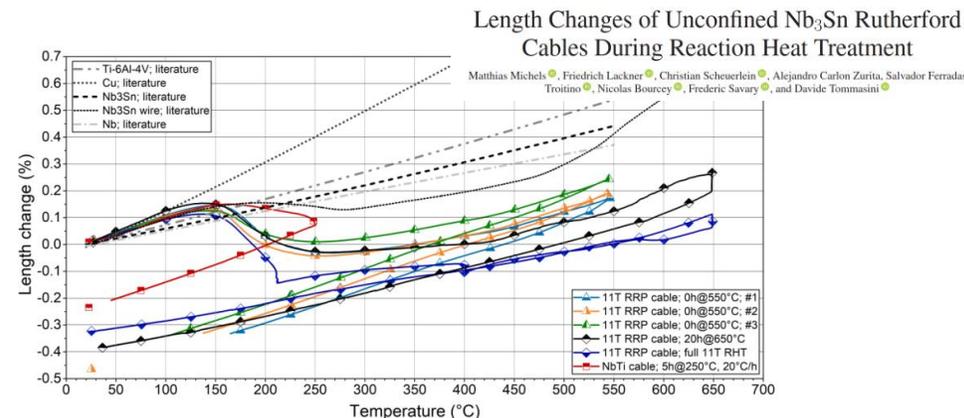


Fig. 5. Comparison of length change behaviour of unreacted Nb_3Sn RRP Rutherford cables (H15OC0220B) with un-annealed Nb-Ti cable and literature values for Ti-6Al-4V [6], Cu [16], Nb [21], bulk Nb_3Sn [16] and Nb_3Sn RRP wires [6].

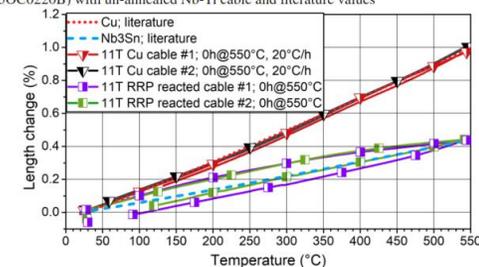
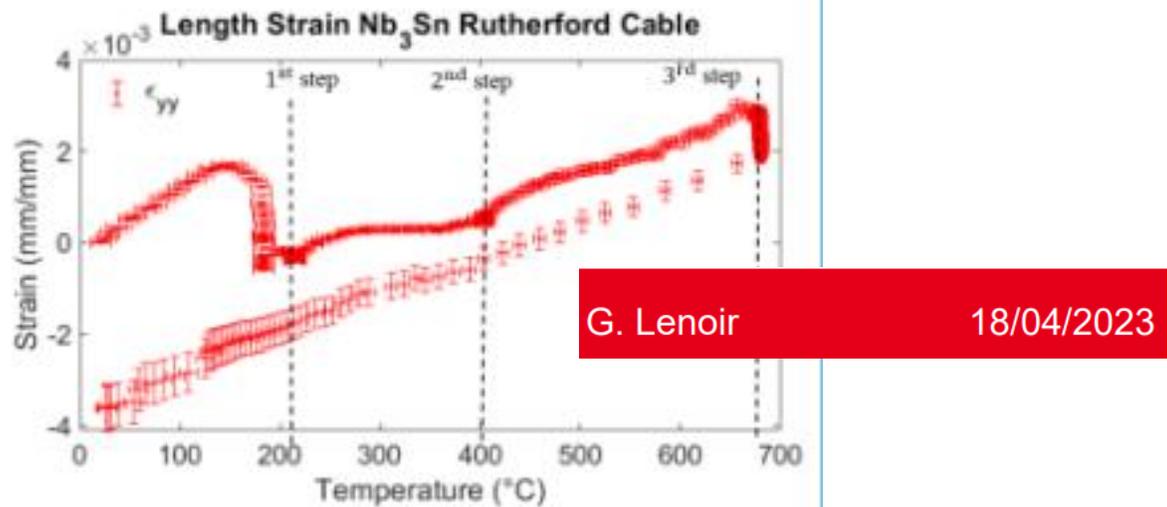
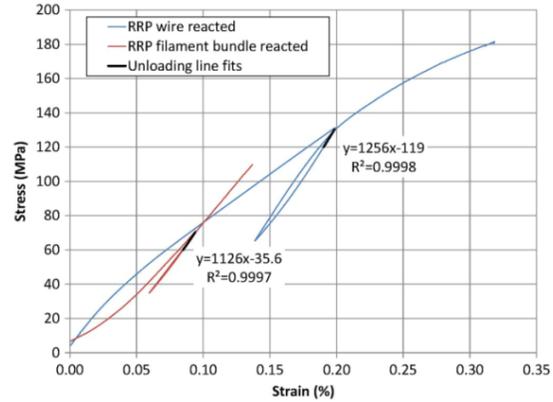


Fig. 6. Relative length changes of un-annealed Cu Rutherford cables and reacted Nb_3Sn RRP Rutherford cables during heat treatment up to $550 \text{ }^\circ\text{C}$ and comparison with literature values for Cu and Nb_3Sn [16].



Elastic modulus of RRP type Nb₃Sn wire



- E is defined as the initial linear slope of the unloading curve.
- Determined elastic modulus of the reacted RRP wire: **126 GPa**

TABLE II
Nb₃Sn ELASTIC MODULI IN AXIAL AND TRANSVERSE DIRECTIONS
CALCULATED FOR THE RRP AND PIT WIRES AT RT AND AT 4.2 K

		PIT B215	RRP #7419
RT	E _{axial}	130	140
	E _{trans}	135	129
4.2 K	E _{axial}	106	127
	E _{trans}	116	104

Fig. 3. Stress-strain curves measured at room temperature on a reacted RRP wire and its extracted filaments.

Mechanical tests with MME:

Nous proposons une matrice d'essais comme suit :

- essais de dilatométrie 20-650-20C sur brins:
 - direction axiale :
 - 3x essai sous faible force
 - 3x essai sous traction a 3 N (F_{max})
 - 3*Essai sous traction a 1.5 N
 - Direction transversale
 - 3x Essai à faible force
- Essais de « traction » de cables sous temperature contrôlée
 - 3x Traction à température ambiante → rigidité et Poissons
 - Cycle 20-650-20C :
 - 3x « 0 » force → déformations axiale et transversales
 - 3x F Force → déformations axiale et transversales
 - 3x X déformation axiale ($F=k.X$) → force axiale et déformations transversales

Ici nous procéderons comme discuté pour l'arrimage des éprouvettes (collage céramique) sur des inserts consommables. Un approche similaire a été décrit dans la littérature pour les basses températures (brin brassé a l'étain) avec des bonnes résultats. La mesure des déformations transversales reste compliquée, mais je pense que possible avec le système de Corrélation Digitale D'image.

Nous travaillons déjà sur le dessin des outillages. Je contacterai prochainement Hervé Rambeau pour planifier la fabrication (même si je pense que c'est un tout petit truc.).

Au niveau de la production des échantillons, il serait nécessaire de prévoir au moins:

- x15 segments d'au moins 30 mm (dilatométrie)
- x15 segments d'au moins 80 mm (traction)

Comme tu le sais, nous devons facturer no activités. Nous estimons le cout de la campagne en 8000 CHF.

To be added:

- Essais de traction sur brins

Experimental activities

Samples, wires and cables, are available.

Design of the anchoring system is being finalized by MME (no temperature increase above 200 C is required).

Discussion to be planned with Oscar and Thierry about sample preparation and test protocole (Sn retaining, temperature plateau).