DE LA RECHERCHE À L'INDUSTRIE

cea

Mechanical characterization setups at CEA

Maria Durante – CEA Paris-Saclay

Workshop on Nb_3Sn Rutherford cable characterization for accelerator magnets

CIEMAT, Madrid – 17/11/2017

www.cea.fr

CONTENT

Mechanical characterization of impregnated stacks

- RT and 4K Young modulus mesurement,
- Thermal shrinkage coefficient measurement,
- Stack preparation

Mechanical characterization of ceramic-insulated stacks

- Which sample for non impregnated stacks ?

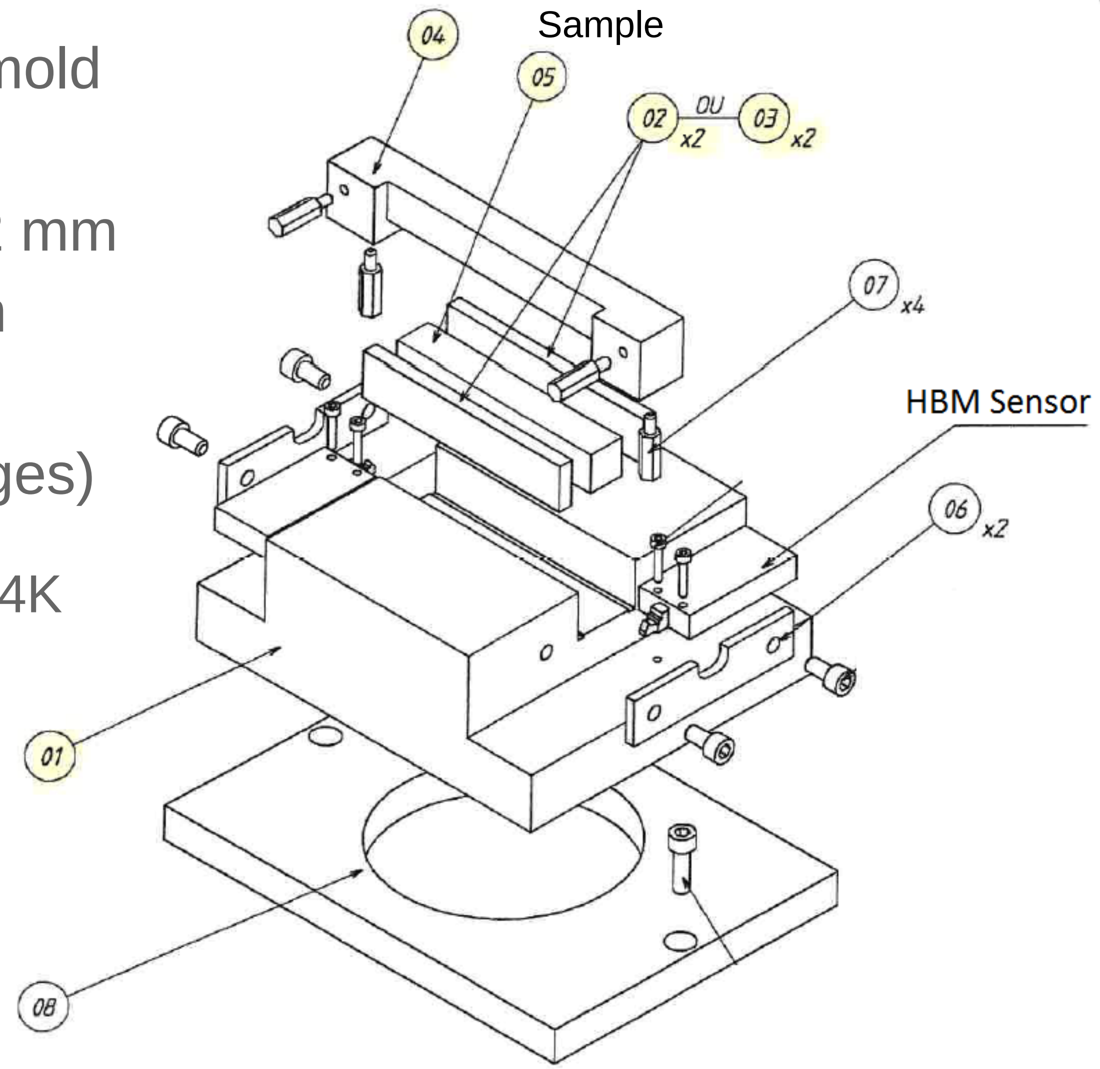
YOUNG MODULUS

- INSTRON Tensil/Compression machine 4206
- Calibrated INSTRON 2518 load cell – 150 kN
- LHe cryostat

- A tensil machine with a load cell up to 300 kN will be equipped for this kind of measurement in the future

YOUNG MODULUS

- U-shaped Stainless steel mold
- Stack width : from 12 to 22 mm
- Stack lenght up to 120 mm
- 2 HBM Sensors (strain gages)
  - +/- 2.5 mm
  - calibrated at RT, 77K and 4K



YOUNG MODULUS

- Setup and test procedures has been validated with reference metallic samples

Sample	Number of Tests	293 K
Copper	3	130 ±5
Titanium	3	115 ±1
S. Steel	5	220 ±20

YOUNG MODULUS

- The setup was used to characterize the Nb3Sn cable of CEA R&D Nb3Sn Quadripole model

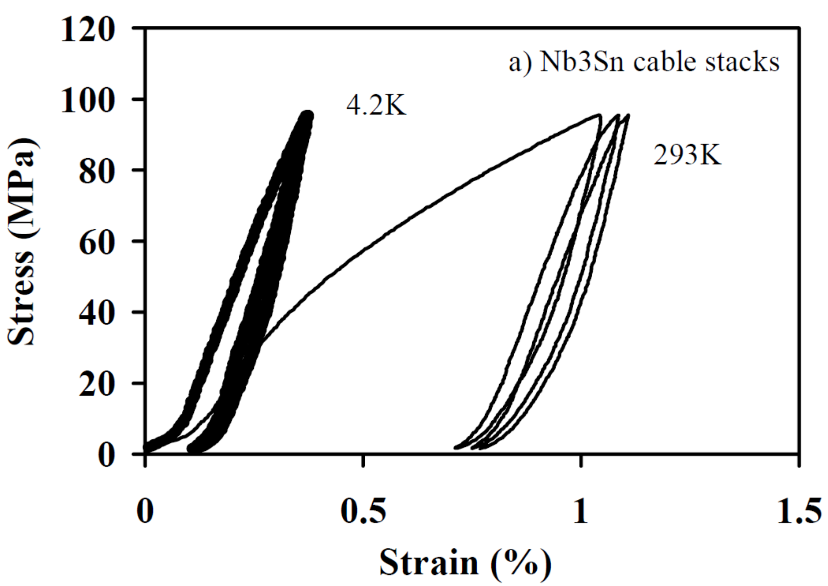
	Nb_3Sn Cable[a]
Strand Diameter	0.825
Number of Strands	36
Cable Width (mm)	15.1
Mid-Thickness (mm)	1.485
Keystone angle	0.94°
Cable Twist (mm)	101
316 L core between the two strand layers of each cable	

- Cable insulated with a 15-mm-wide, 60-µm-thick quartz fiber tape (two layers without overlap).

- Reacted cable stacks vacuum-impregnated with epoxy resin (MY745 resin, HY905 hardener, DY072 and DY073 catalysts)

YOUNG MODULUS

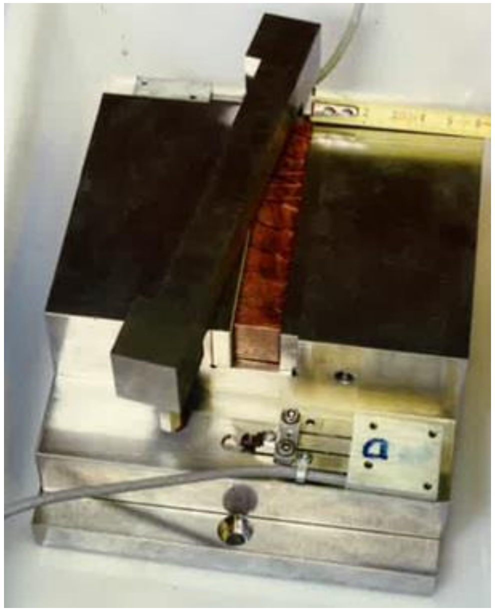
- Non-linear behavior for the first loading on a virgin stack
- Hysteresis between loading and unloading
- More or less stabilized after three loadings



Sample	Number of Tests	293 K	Number of Tests	4.2 K
Nb3Sn stacks	6	33 ±1	2	45 ±1
Resin	5	4.2 ±0.2	2	8.6 ±0.2

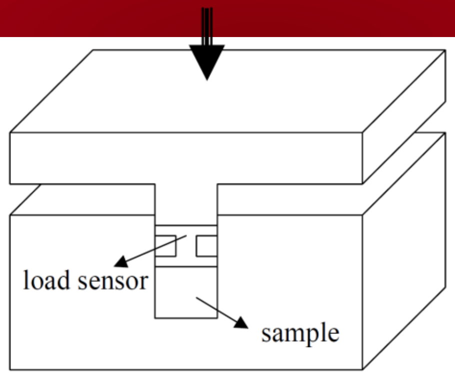
YOUNG MODULUS

- 3 successive cycles, between 2.5 kN and 150 kN
- Displacement sensor zero reset at 2.5 kN
  to compensate small geometric defect of the samples
- Crosshead displacement speed of 0.2 mm/min



- Mold rigidity is measured before each test using a reference aluminum alloy bar

THERMAL SHRINKAGE COEFFICIENT



U-shaped stainless steel mold

T-shaped upper plate bolted to the mold
after having put the sample under compression

Load sensor : Stainess steel instrumented I beam

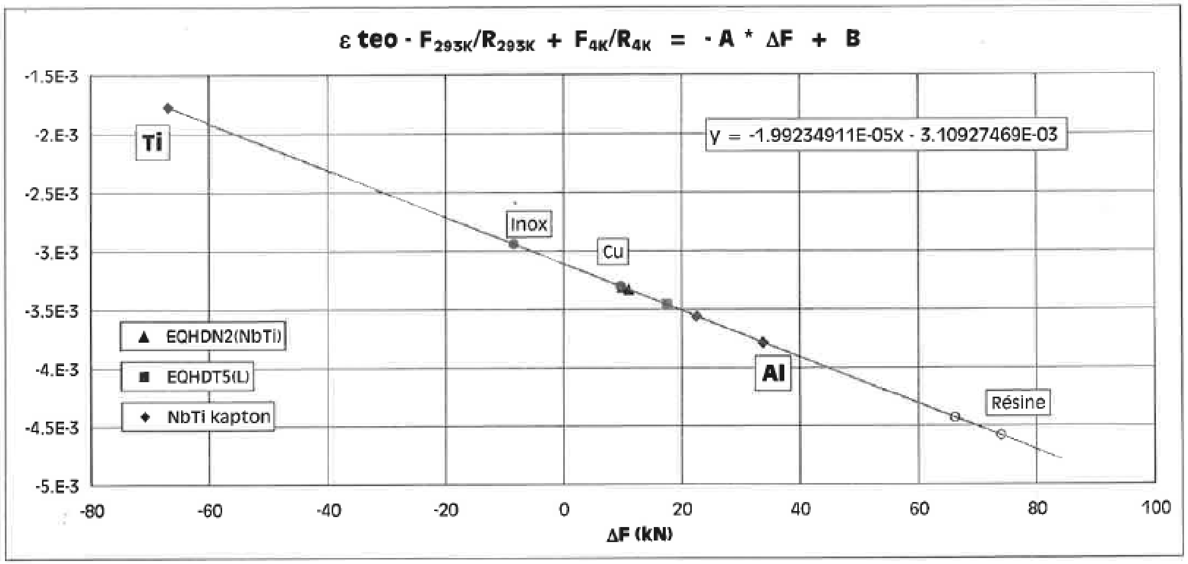
- 4 half bridges of strain gages
- 1 thermal compensation gage

- Stack width : 15.37 mm
- Stack lenght : 100 mm

- New mold and beam for wider cables is necessary

THERMAL SHRINKAGE COEFFICIENT

Al and Ti reference bars are use to determine the coefficient for the other samples



Sample	Number of Tests	Test Result (mm/m)	Literature (mm/m)
Copper	1	–3.4	–3.24
S. Steel	1	–2.9	–3.06
Resin	2	–18.8 ±0.1	–11.6 up to –14
Nb_3Sn Stacks	2	–3.9 ±0.1	–3.50 –3.30
Impregnated NbTi Stacks	2	–3.8 ±0.1	–3.55
NbTi + Kapton Stacks		–4.96	

Integrated thermal shrinkage coefficient
between 293 K and 4.2 K

STACK PREPARATION

Heat Treatment

- L shaped Reaction molds, screwed
- Cavity adapted to the cable dimensions
- Strands ends melted by TIG before heat treatment

Impregnation

- Impregnation mold with ad-hoc insert
- Closed impregnation circuit to allow insertion and circulation of resin at low pressure
- Bladder for compression after resin insertion

NEXT TEST CAMPAIGNS

Young modulus measurement

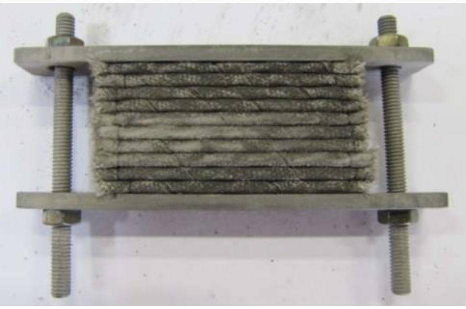
- Measurement setup is ready for tests
- New calibration of the HBM sensor is ongoing
- Next test campaign on MQXF, 11T and FRESCA2 cables

Thermal shrinkage coefficient

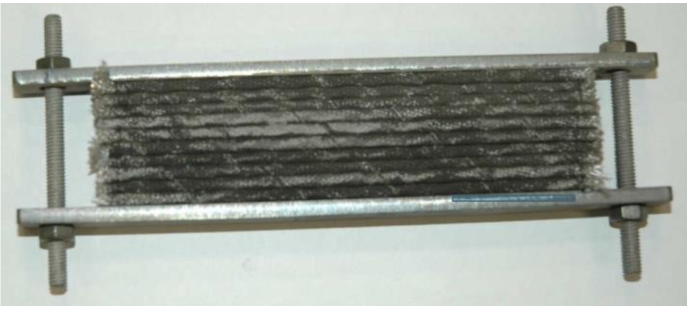
- The existing setup needs to be adapted for wider cables.
- Commissioning and validation of the new setup is foreseen by mid of next year.

Mechanical characterization of Nb3Sn cable with ceramic insulation

- Which samples for non impregnated cables ?



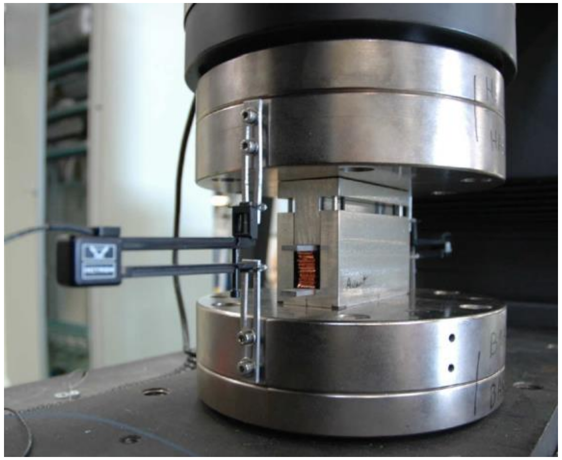
Short stack (S)



Long stack (L)

Experimental setup (RT)

- 300 kN load cell
- 2 symmetrical extensometers

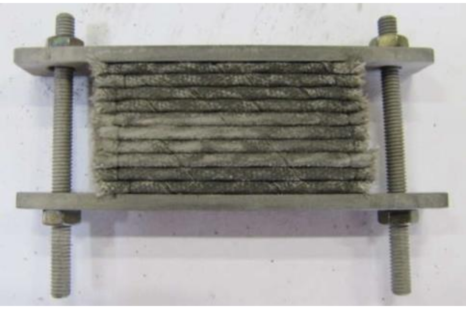


Courtesy F. Rondeaux, P. Manil

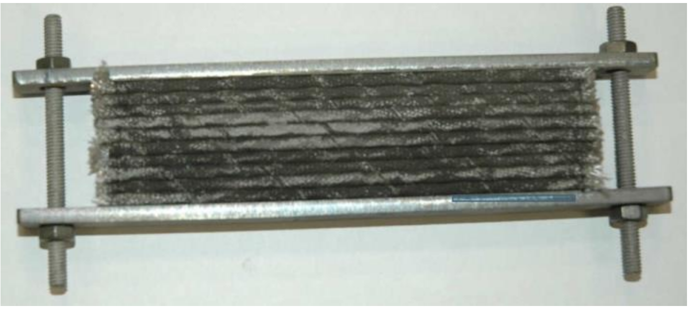
CERAMIC INSULATED STACKS

Mechanical characterization of Nb3Sn cable with ceramic insulation

- Which samples for non impregnated cables ?

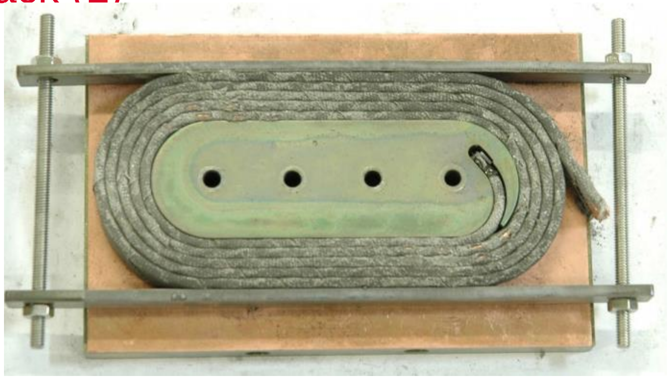


Short stack (S)



Long stack (L)

But : risk of cable untwisting

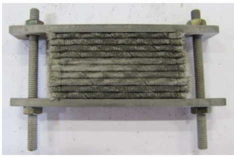


Short Racetrack (R)

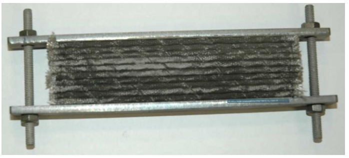
Courtesy F. Rondeaux, P. Manil

Mechanical characterization of Nb3Sn cable with ceramic insulation

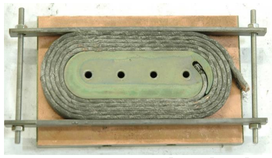
- Stacks limited to 25 Mpa (S) - 40 Mpa (L)
- Racetrack configuration improves cable cohesion and stack rigidity



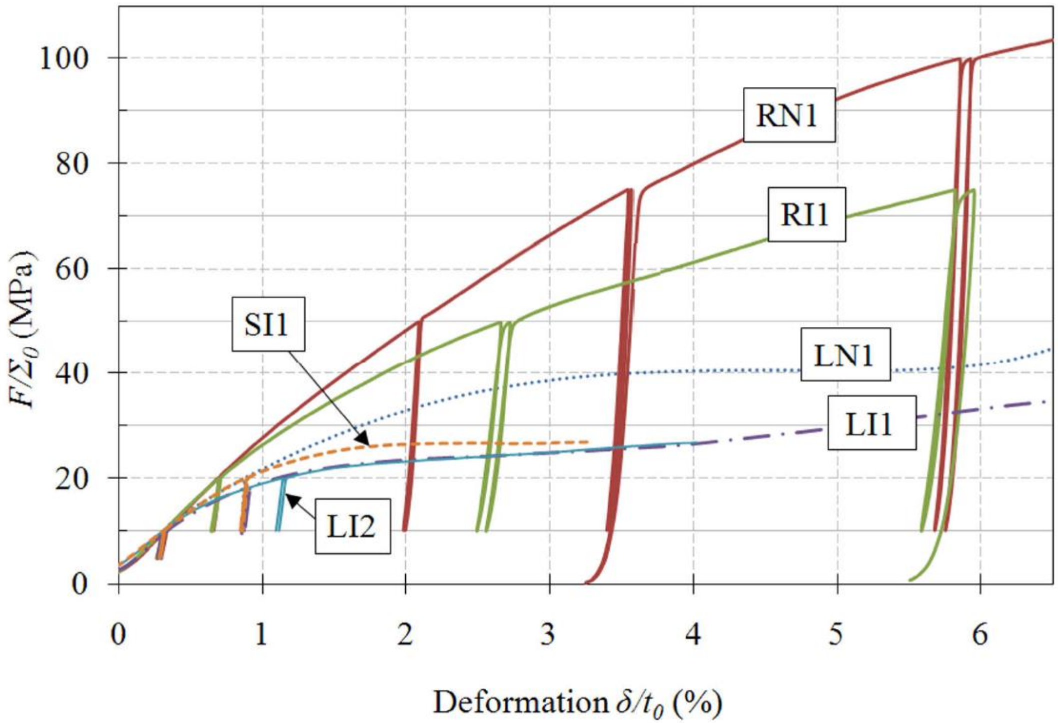
Short stack (S)



Long stack (L)



Short Racetrack (R)

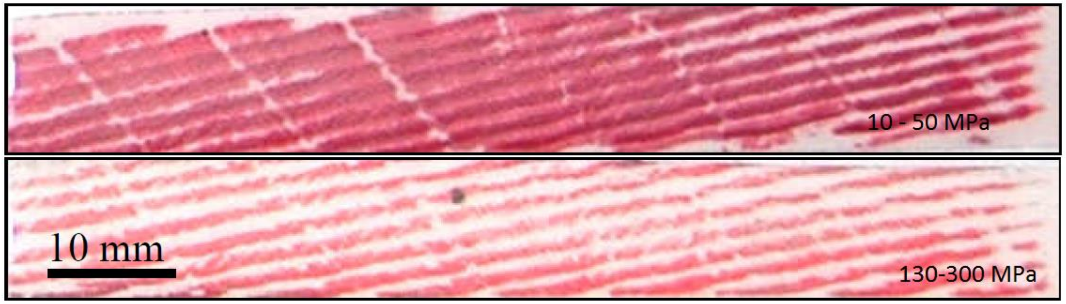


Courtesy F. Rondeaux, P. Manil

CERAMIC INSULATED STACKS

Mechanical characterization of Nb_3Sn cable with ceramic insulation

- For pressures above 50 MPa, the ceramic insulation mechanical properties are insufficient and cracks appear.
- FUJI™ Prescale film was used to evaluate the stress repartition on the sample surface : about 90 % of the contact surface sees pressures higher than 10 Mpa, BUT about 30 % of the surface reaches high stress over 130 MPa.



Courtesy F. Rondeaux, P. Manil