NATIONAL HIGH MAGNETIC FIELD LABORATORY

Composite Mechanical Properties of Coils Made With Nickel-Alloy Laminated Bi-2223 Conductors

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Abstract

High-temperature superconducting magnet coils made with Sumitomo Type HT-NX are complex composite structures composed of Bi-2223 conductor filaments, silver matrix, solder, nickel-alloy laminations, polymer insulation, and epoxy or wax. The mechanical properties of these composites are required inputs to a correct stress analysis. Mechanical test specimens composed of several layers of insulated conductor are prepared by cutting to length, stacking and epoxy impregnation. Mechanical tests are performed in liquid nitrogen and liquid helium. Elastic constants are found from tensile strain measurements in the conductor longitudinal, or coil hoop, direction and from compressive strain measurements in the conductor transverse, or coil radial and direction. Results are compared with rule-of-mixtures and finite element calculations.

Test Specimens

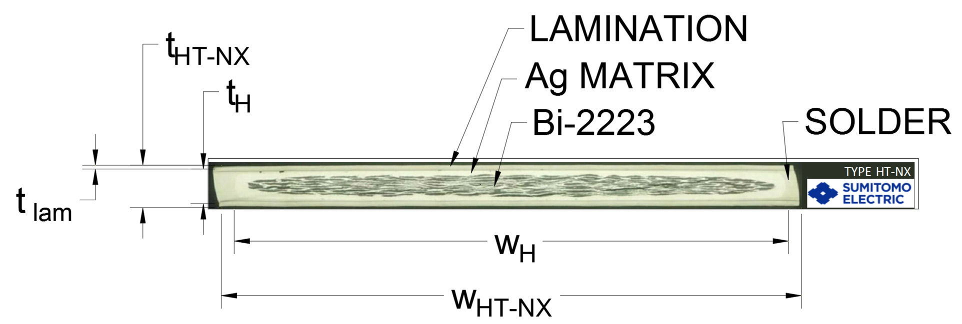
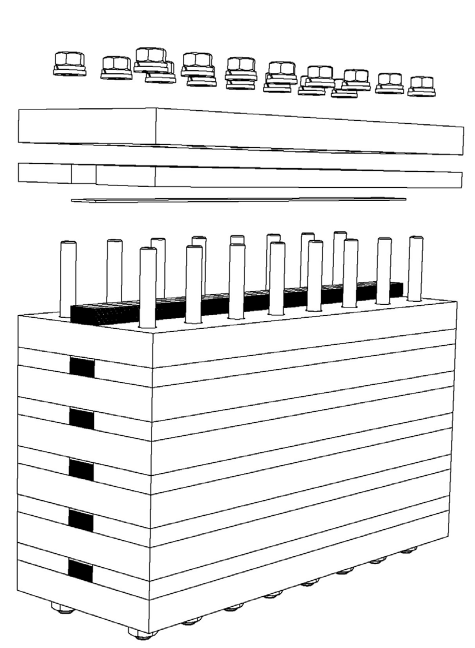
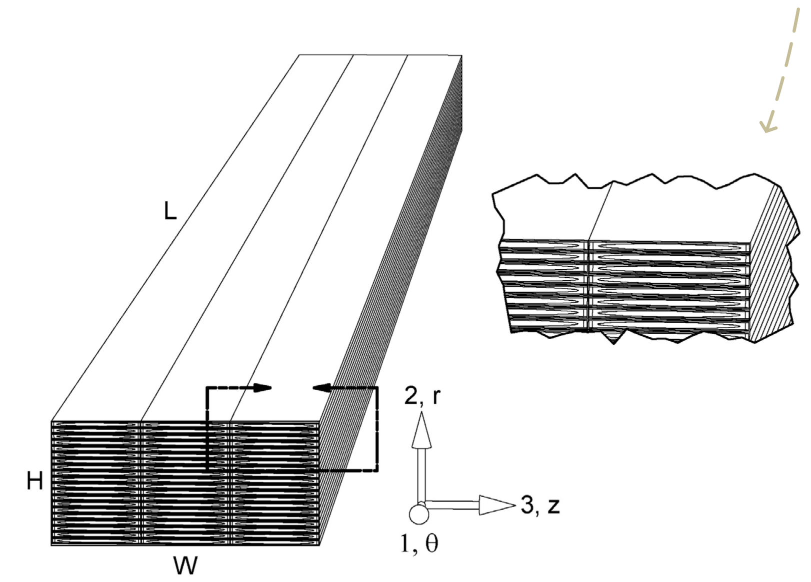


TABLE I
Sumitomo Type HTi-NX Conductor and Composite Specimen Dimensions

Component, Dimension	Symbol	Value (mm)
Type H conductor and silver matrix, width	w_H	4.3
Type H conductor and silver matrix, thickness	t_H	0.2
Type HT-NX, laminated conductor, width	w_{HT-NX}	4.5
Type HT-NX, laminated conductor, thickness	t_{HT-NX}	0.31
Ni-alloy laminations, thickness per side	t_{lam}	0.03
Kapton insulation, thickness per side	t_{kapton}	0.025

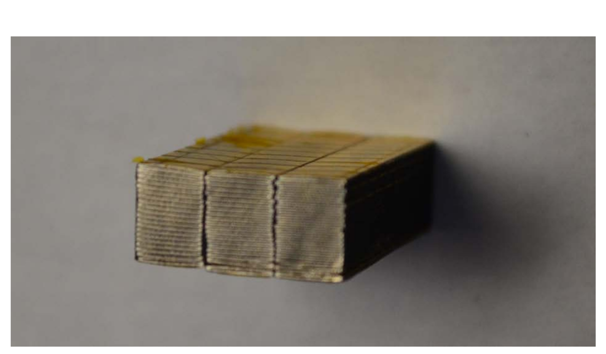


Composite specimen mold



Composite specimen
$L_{compressive}$ = 50 mm, $L_{tensile}$ =200 mm, W=13.7 mm, H=6.5 mm

Tensile composite specimens

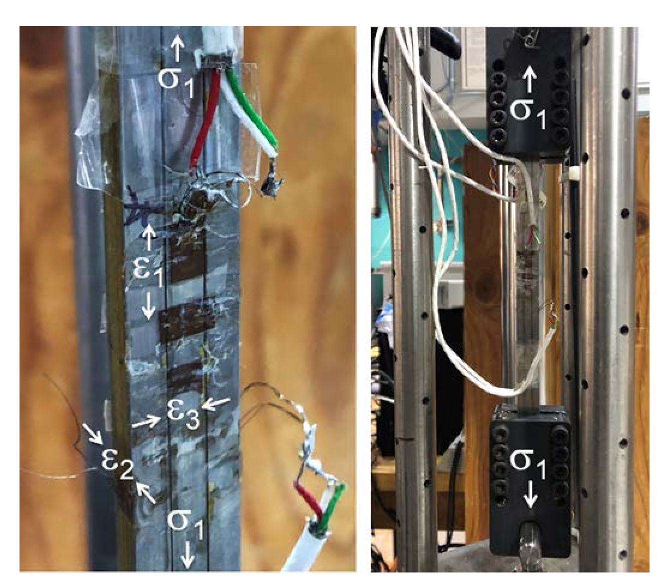


Compressive composite specimen

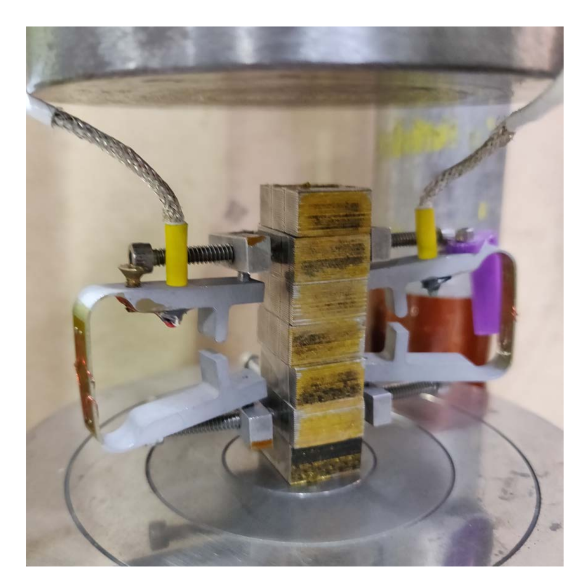
Tests

Re-entrant load frame with tensile specimen mounted in grips

Mechanical test facility with cryostat in place and test in progress



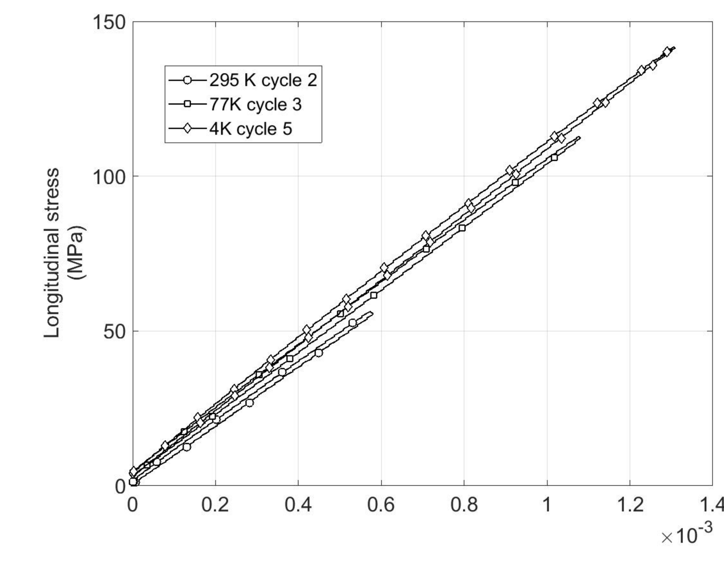
Detail of strain gauges, load path and strain measurements

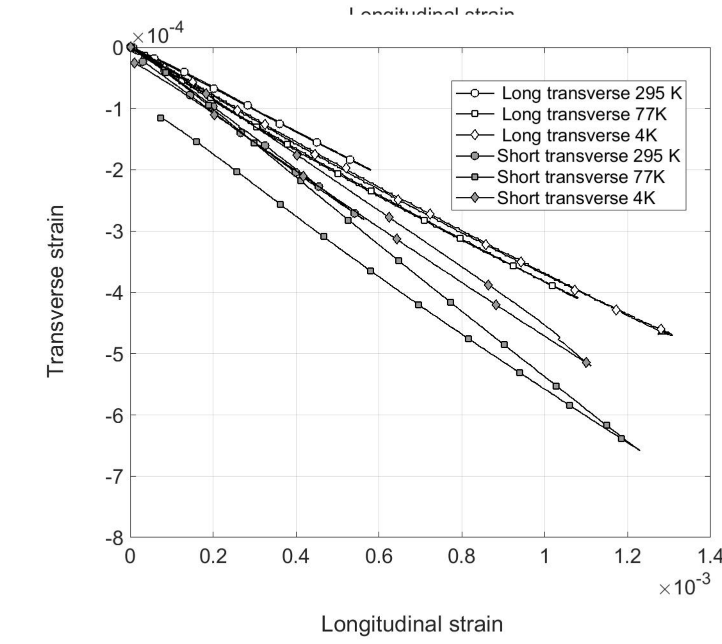


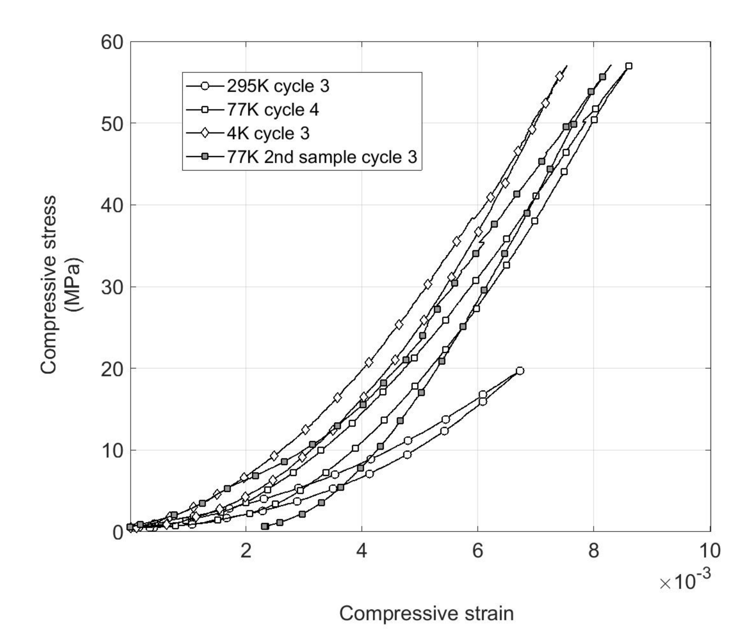
Transverse strain specimens, stacked, with extensometers—to determine elastic modulus in the short transverse direction

Results

From measurements





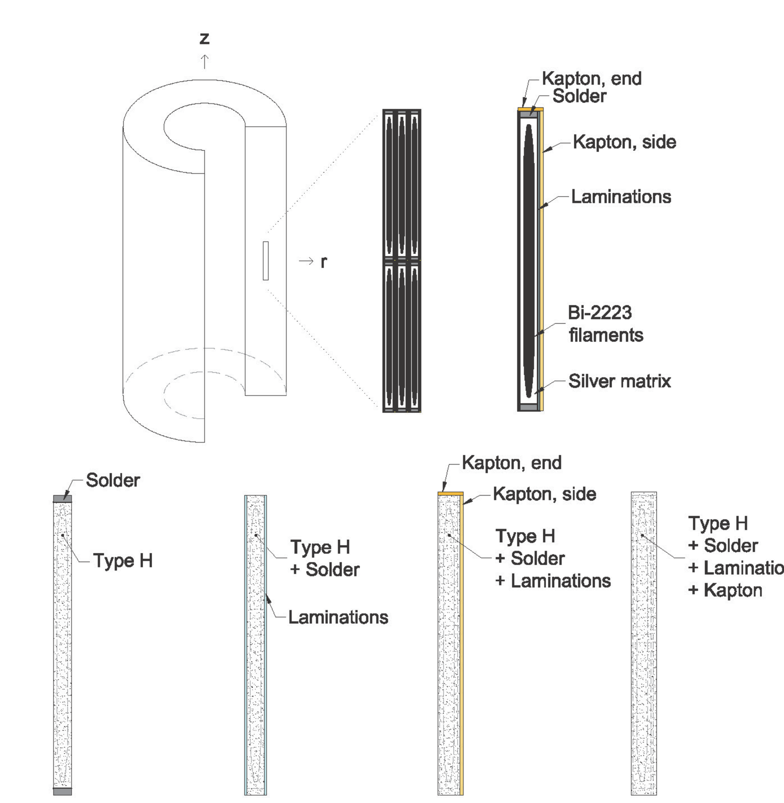


	295 K	77 K	4 K	Units
E_{11}	93.5	98.3	105	GPa
E_{22}	4.4	10.2	11.1	GPa
ν_{12}	0.5	0.51	0.46	
ν_{13}	0.35	0.35	0.37	

Calculation inputs

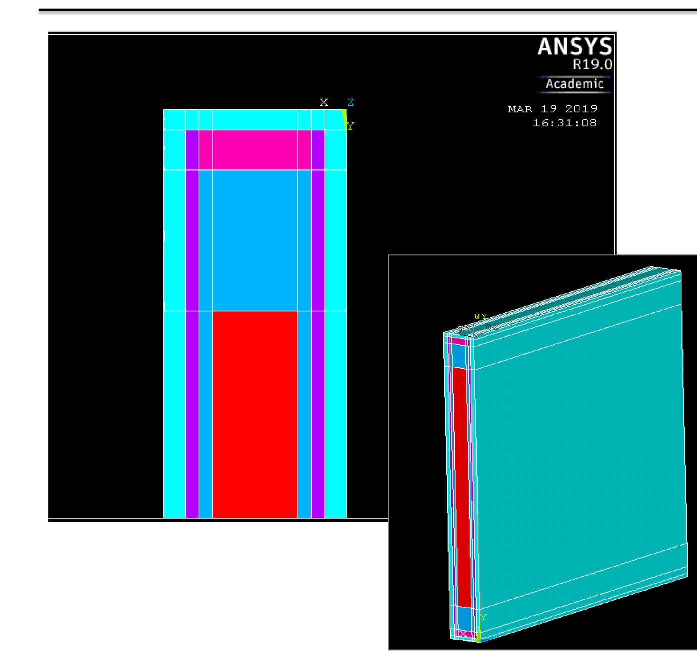
Constituent	Area	Elastic modulus	Poisson's ratio	Shear modulus
		E	ν	G
Units	mm^2	GPa		GPa
Bi-2223 filaments	0.327	103	0.21	43
Silver matrix	0.59	77	0.37	28
Solder	0.04	50	0.42	18
Ni-Alloy lamination	0.27	226	0.29	88
Kapton	0.231	5.5	0.34	2

From Rule of Mixtures calculation



Temp	295 K	Units
E_{11}	99	GPa
E_{22}	37	GPa
E_{33}	87	GPa
G_{12}	10	GPa
G_{23}	10	GPa
G_{31}	30	GPa
ν_{12}	0.32	
ν_{23}	0.13	
ν_{13}	0.32	
ν_{21}	0.12	
ν_{32}	0.30	
ν_{31}	0.28	

From Finite Element calculation



Temp	295 K	Units
E_{11}	93	GPa
E_{22}	24	GPa
E_{33}	72	GPa
G_{12}	6.6	GPa
G_{23}	6.4	GPa
G_{31}	25	GPa
ν_{12}	0.37	
ν_{23}	0.49	
ν_{13}	0.31	
ν_{21}	0.28	
ν_{32}	0.42	
ν_{31}	0.28	

Acknowledgements and References

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