Laboratoire de Mécanique et d'Acoustique

Study of the winding process of a HTS tape around a round core for CORC cable production

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21/10/2026



amU Aix Marseille Université

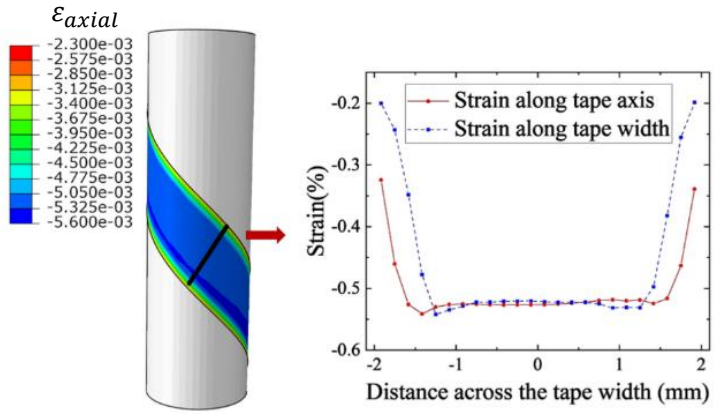
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Objectives of the study

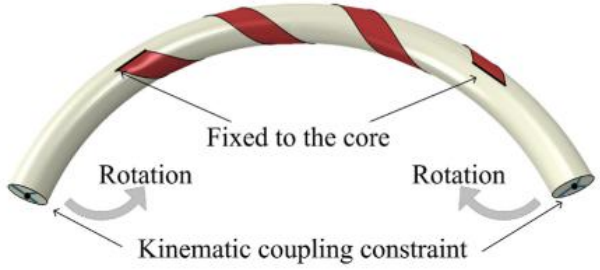
Overall objective: Study of the strain developed in a ReBCO tape during the different steps from its manufacturing to its use

Winding of one (or several) ReBCO tape(s) around a core

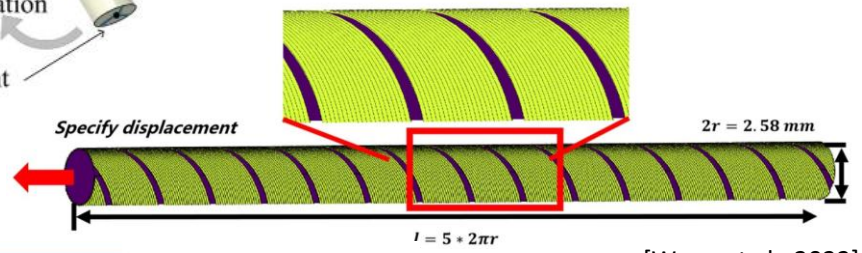


[Hu et al., 2021]

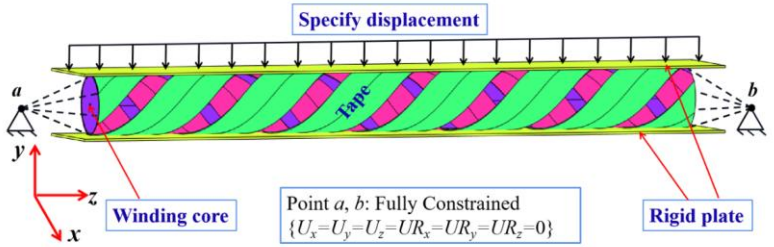
Mechanical loading of CORC cable



[Hu et al., 2021]



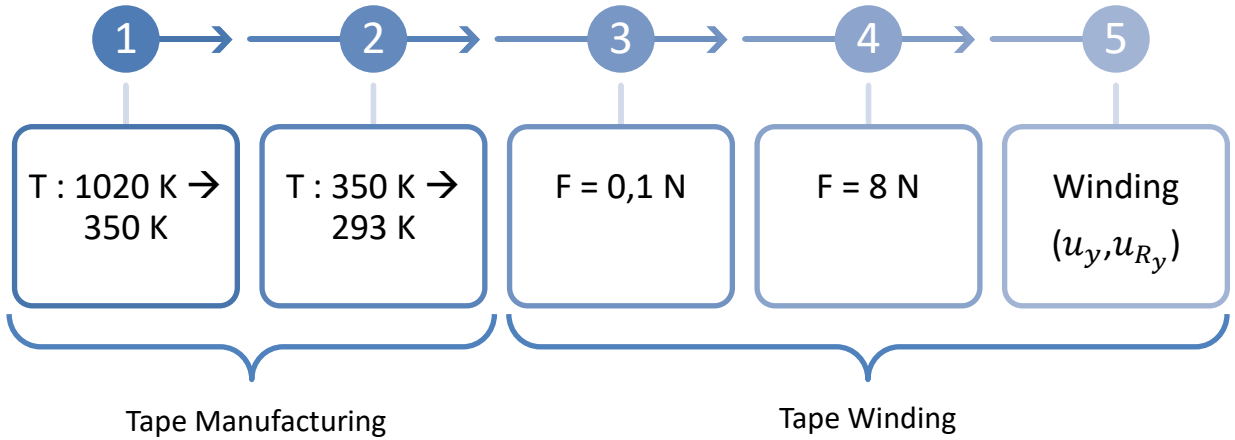
[Wang et al., 2022]

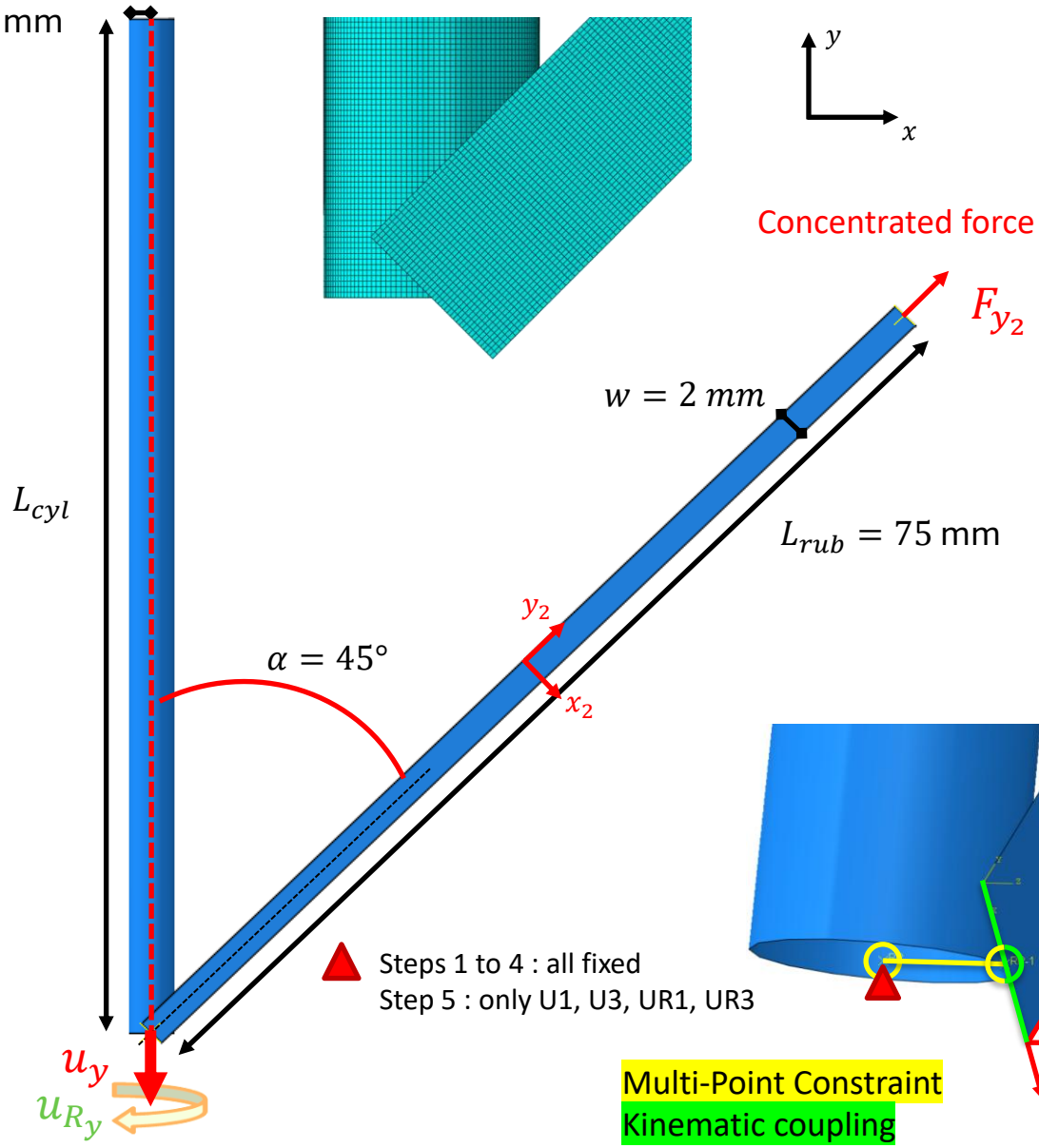


[Yan et al., 2022]

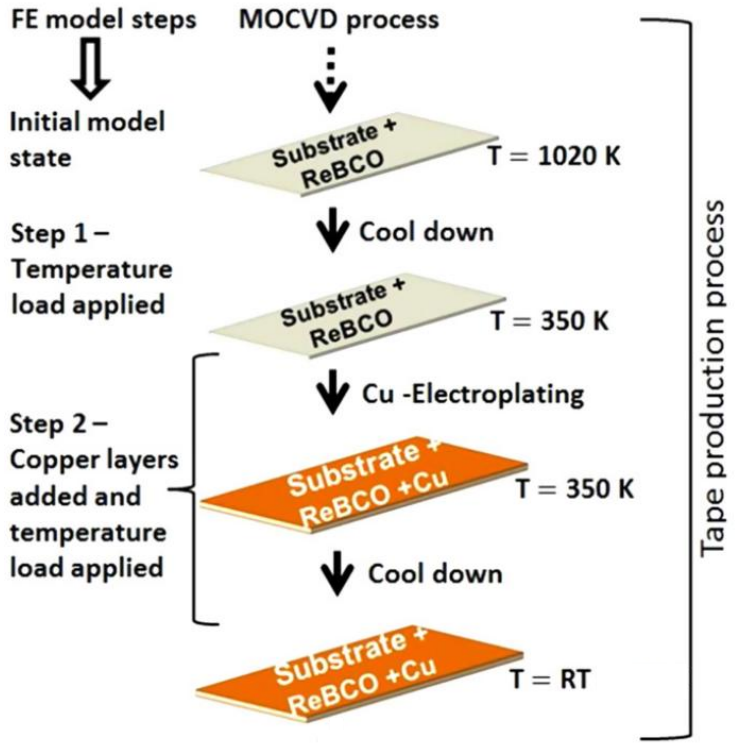
Numerical model

- Round core = shell, rigid body (R3D4 elements)
  Tape = 2D shell (S4R elements), composite layup
- Interaction : node-to-surface contact (friction $\mu = 0{,}2$)
- Steps (quasi-static calculation, Abaqus/Standard) :





Tape manufacturing and material properties

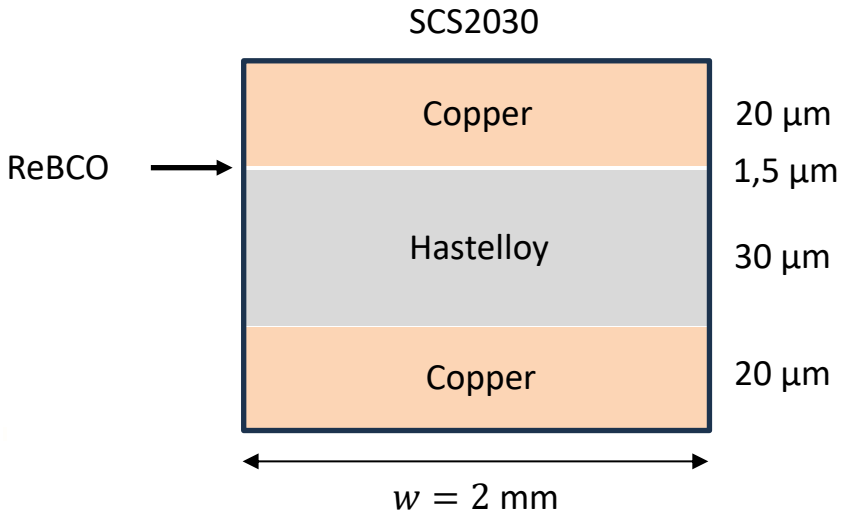


[Ilin et al.2015]

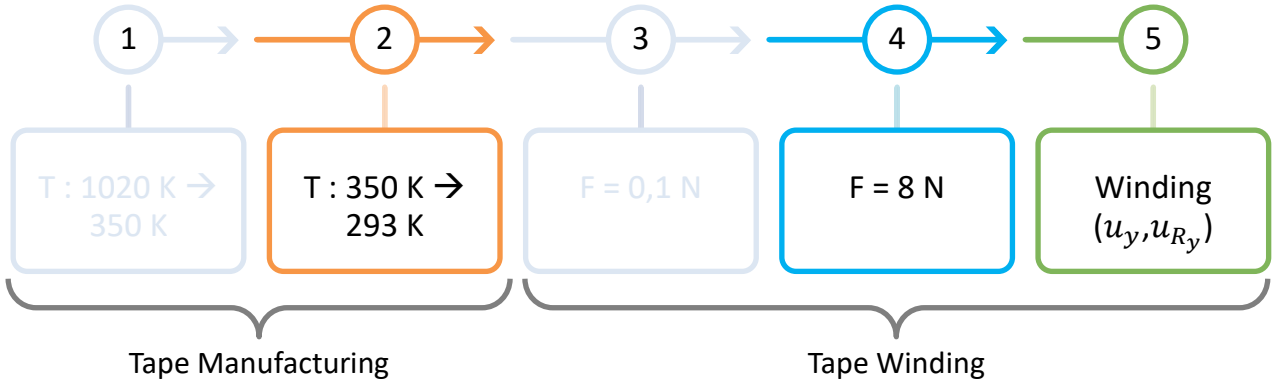
- Activation of the Cu layers as they are deposited onto {substrate + ReBCO}
- Before the copper deposition temperature (350 K):
  Cu has negligible Young's modulus (1.10^{-8} MPa)
- Properties at 293 K

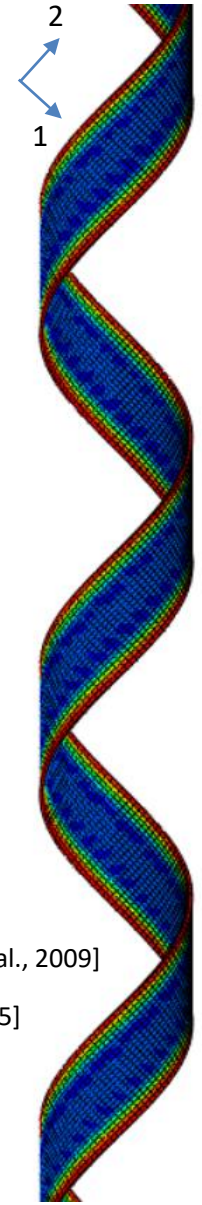
	Density (kg/m³)	Young's modulus (GPa)	Poisson coefficient	Yield stress (MPa)	Expansion coefficient (K^{-1})
Copper	8960	80	0,34	120	1.77E-05
ReBCO	6300	157	0,3	-	1,1E-5
Hastelloy	8890	223	0,307	891	1,34E-5

[Anvar et al.2018]



Evolution of the ReBCO layer strain during the process





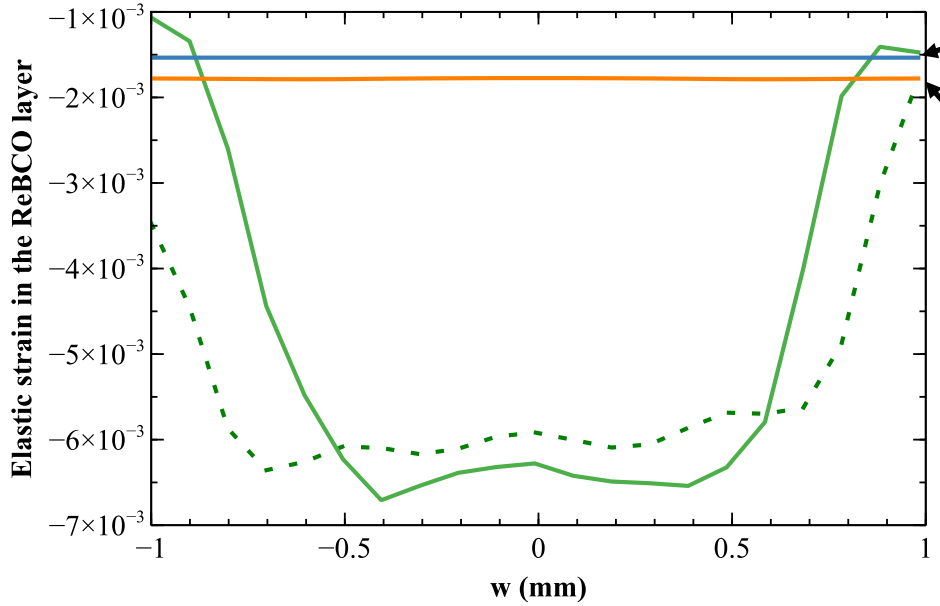
Step 2 – T = 293 K – after tape manufacturing

Step 4 – F = 8 N – after winding tension

Step 5 – after tape winding

Strain along tape width = 11

Strain along tape axis = 22



After 8 N winding tension application :

$\varepsilon_{22} = \varepsilon_{11} = -0{,}15\ \%$

[Anvar et al.2018] : $\varepsilon = -0{,}13\ \%$

After tape production at RT :

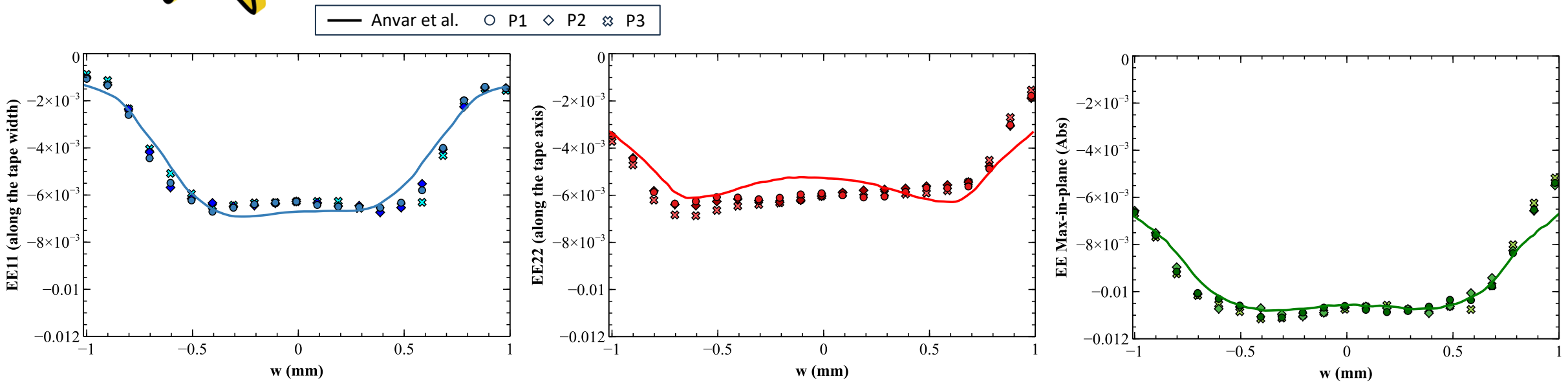
$\varepsilon_{residual\ strain} = -0{,}18\ \%$

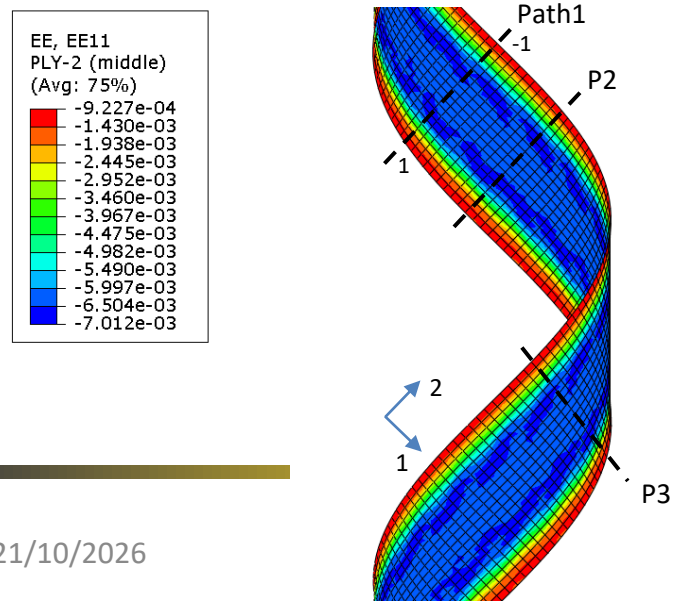
Table 4. Residual strain in the ReBCO layer of SCS4050 tape at RT and 77 K.

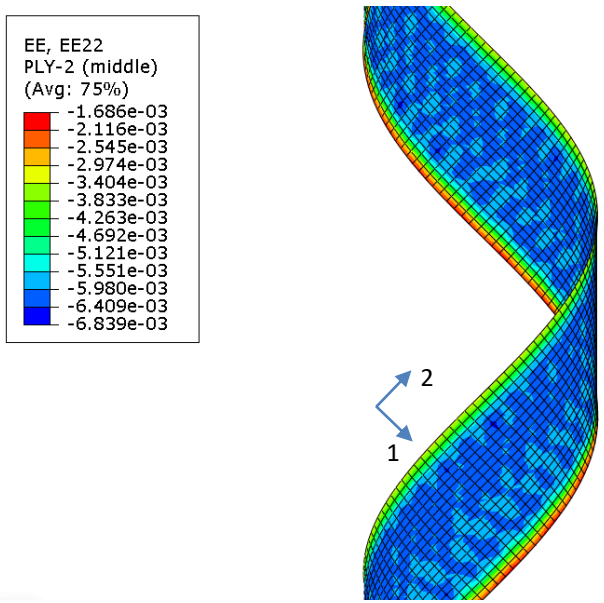
	ε_{ReBCO} (%), RT	ε_{ReBCO} (%), 77 K	
Analytical [5]	–0.17	–0.26	[Osamura et al., 2009]
Experiment [5]	–0.20	—	
FEM	–0.17	–0.24	[Ilin et al., 2015]
FEM	-0,15%	[Anvar et al., 2018]	

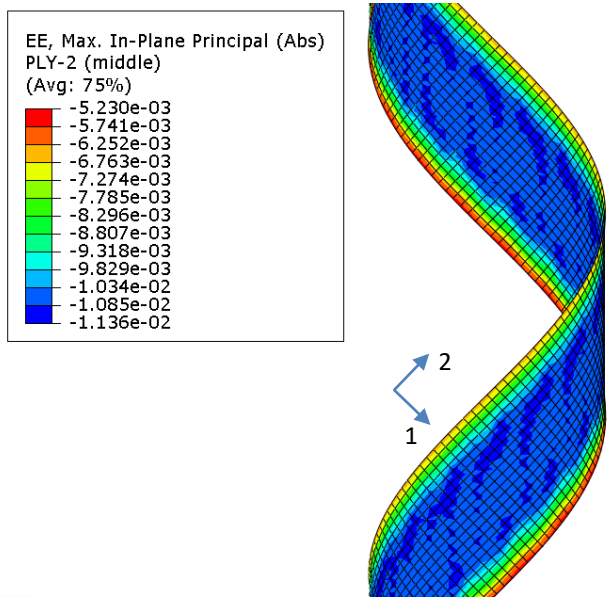
Validation of the numerical model:

Elastic strain developed in the ReBCO layer [Anvar et al.,2018]





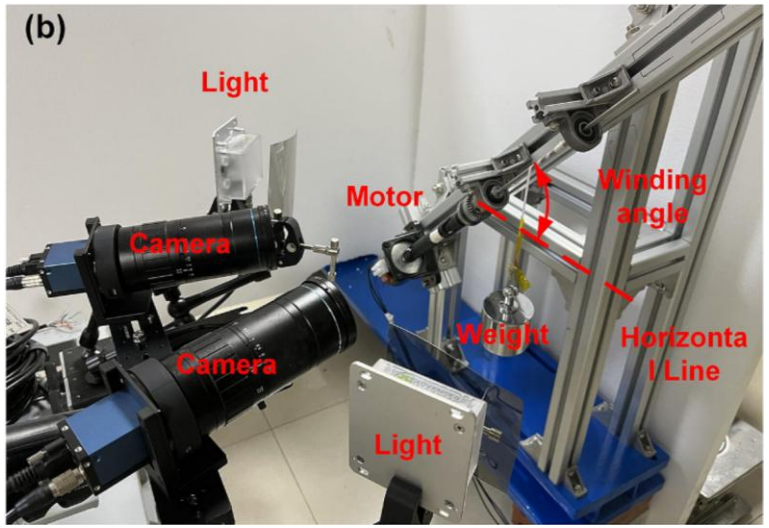


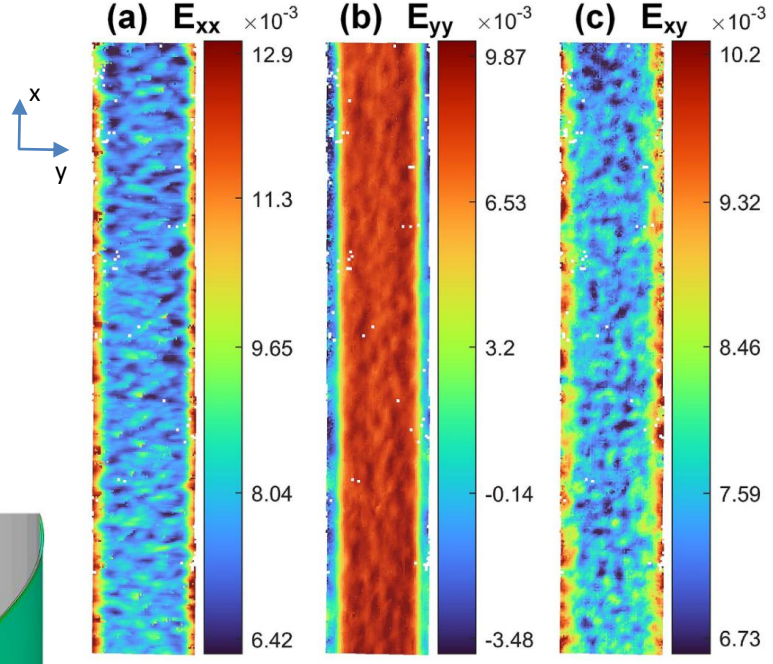


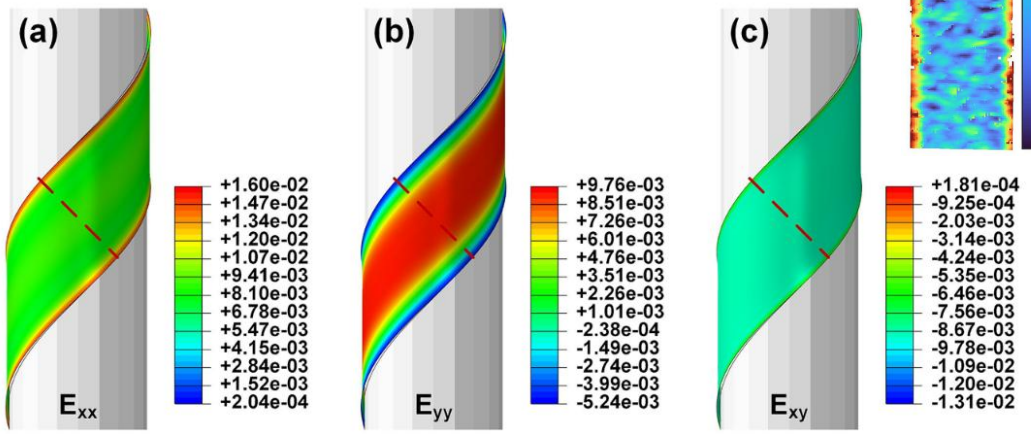
Validation of the numerical model:

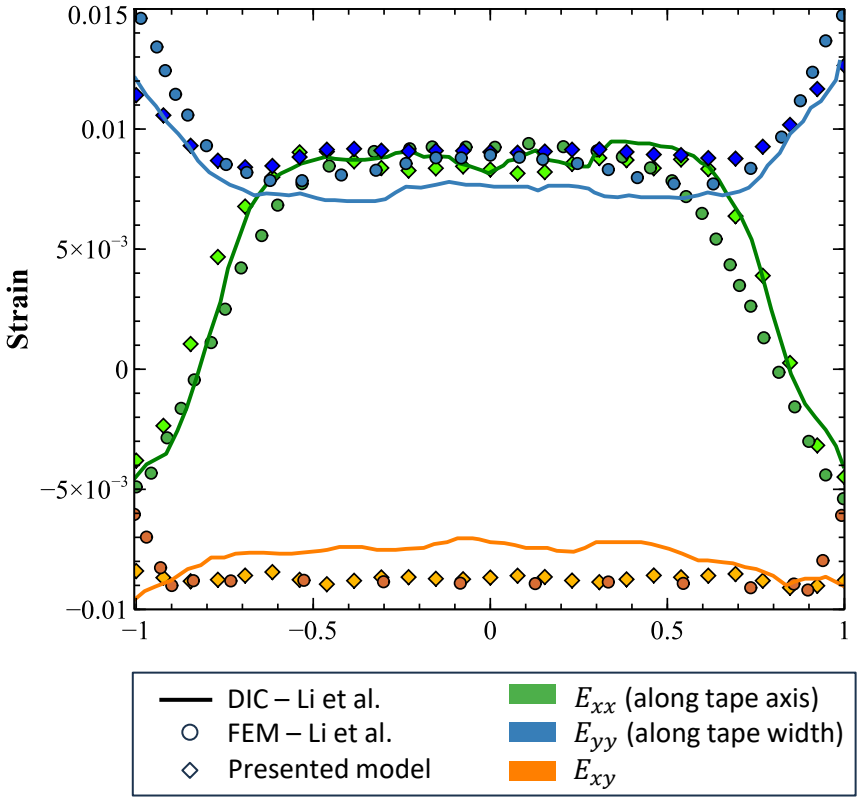
Strain of the tape envelope [Li et al.,2023]

$\alpha = 45°$, $R = 2{,}5$ mm, $F = 10$ N, $w = 4$ mm, ReBCO layer faces outward







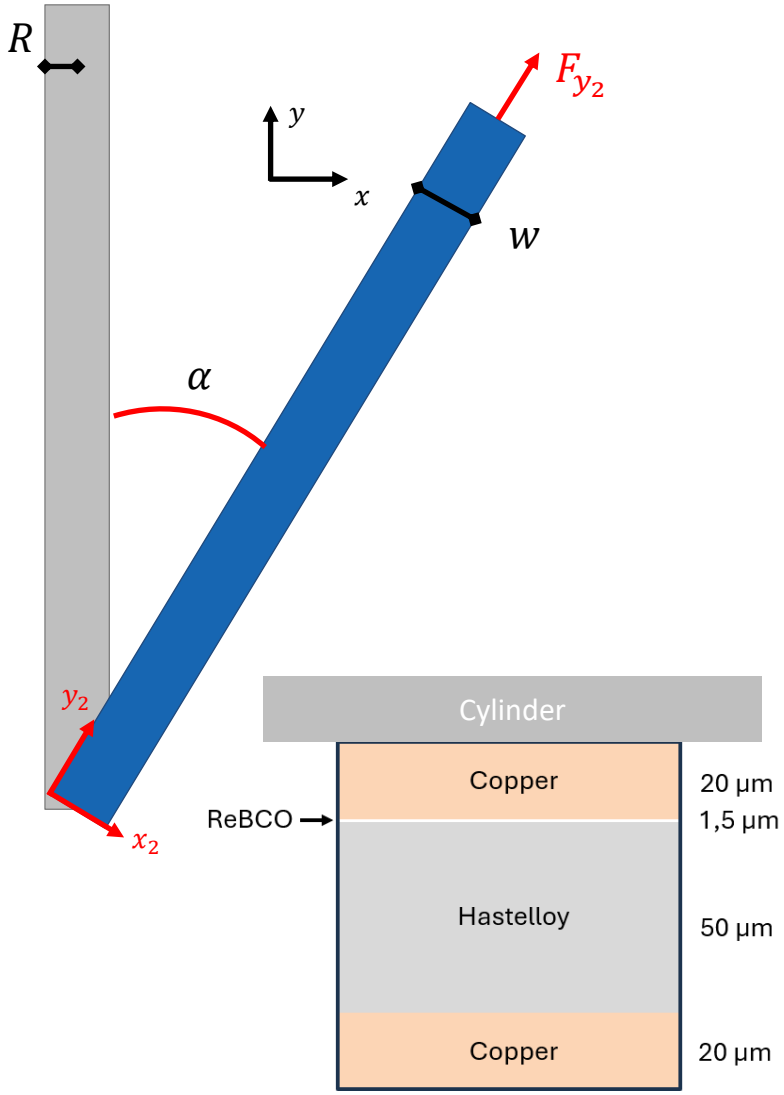


Li et al., 2023: Deformation and crack prediction of CORC cable induced by Poisson effect: Theoretical modeling and experimental validation, *Engineering Fracture Mechanics*

Parametric study

Parameters	Range of values
Winding angle (°)	30 – 45 – 60
Core radius (mm)	1,6 – 2,5 – 3,5
Winding tension (N)	8 – 15 – 30
Tape width (mm)	2 – 4 – 6
Hastelloy thickness (µm)	30 – 50

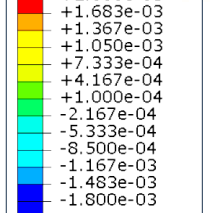
Reference: $\alpha = 45°$, $R = 2{,}5$ mm, $F = 15$ N, $w = 4$ mm, $t_{Hastelloy} = 50$ µm

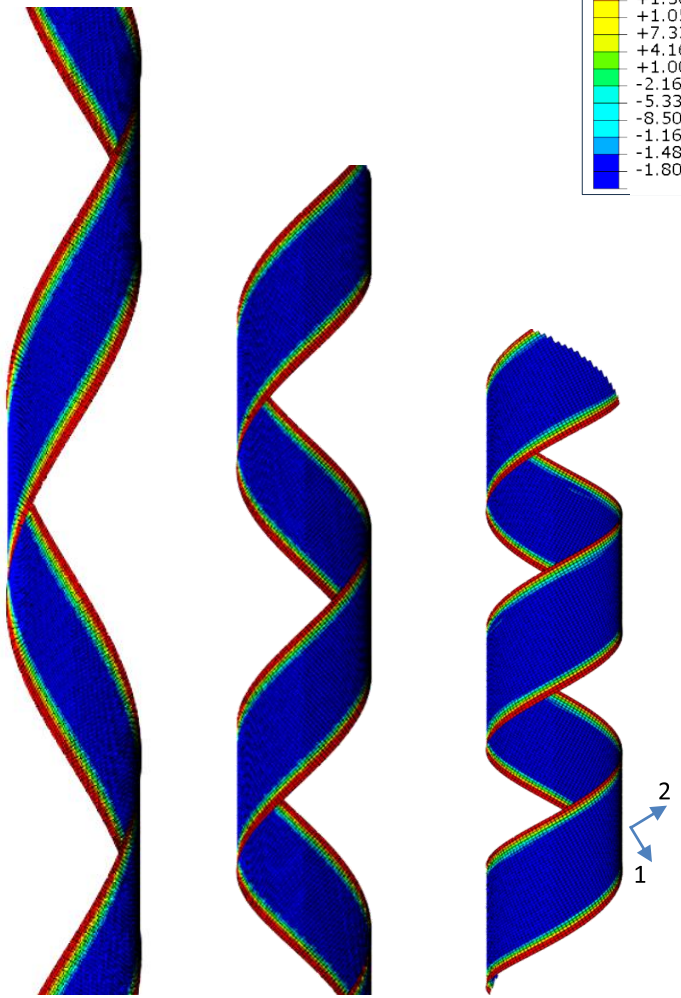


Winding angle

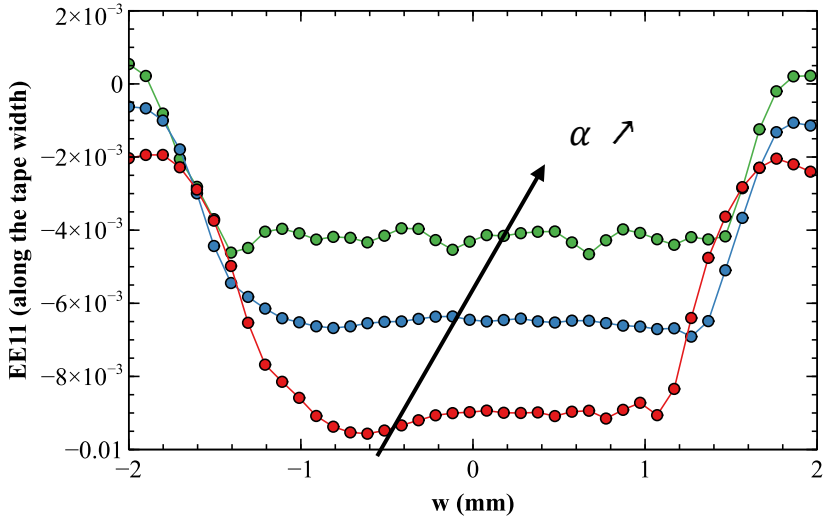
EE = Elastic strain in the ReBCO layer

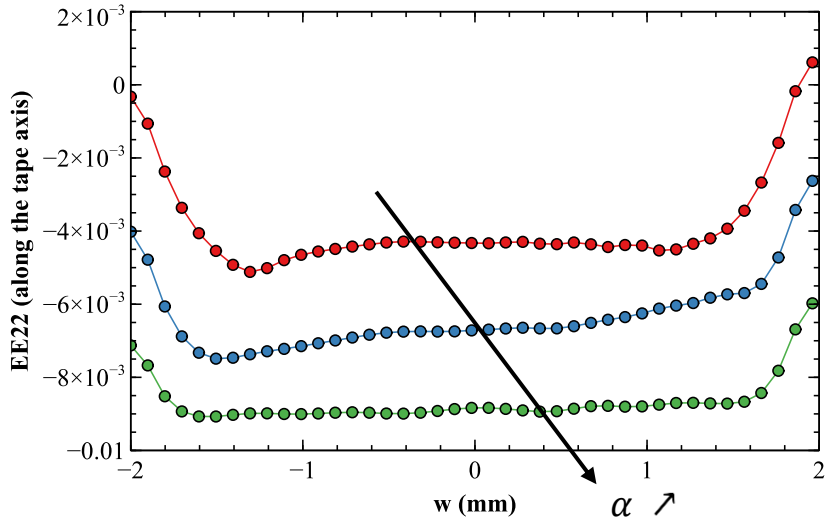


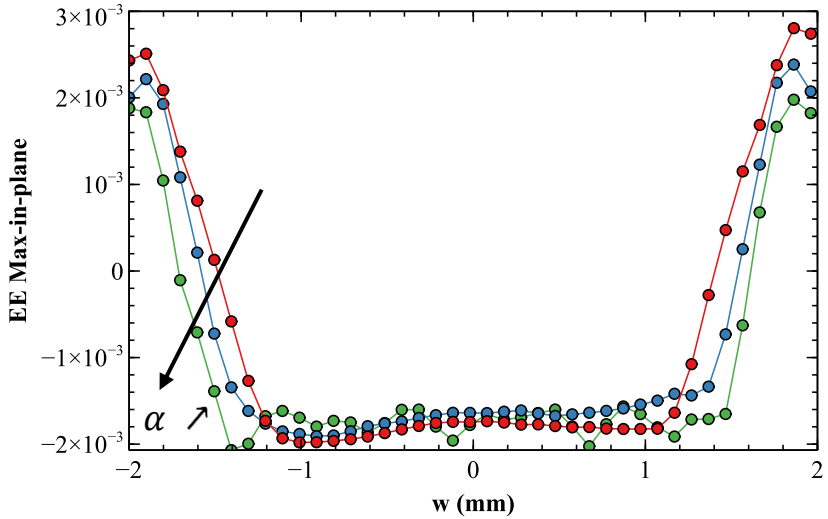




$\alpha = 30°$ $\alpha = 45°$ $\alpha = 60°$







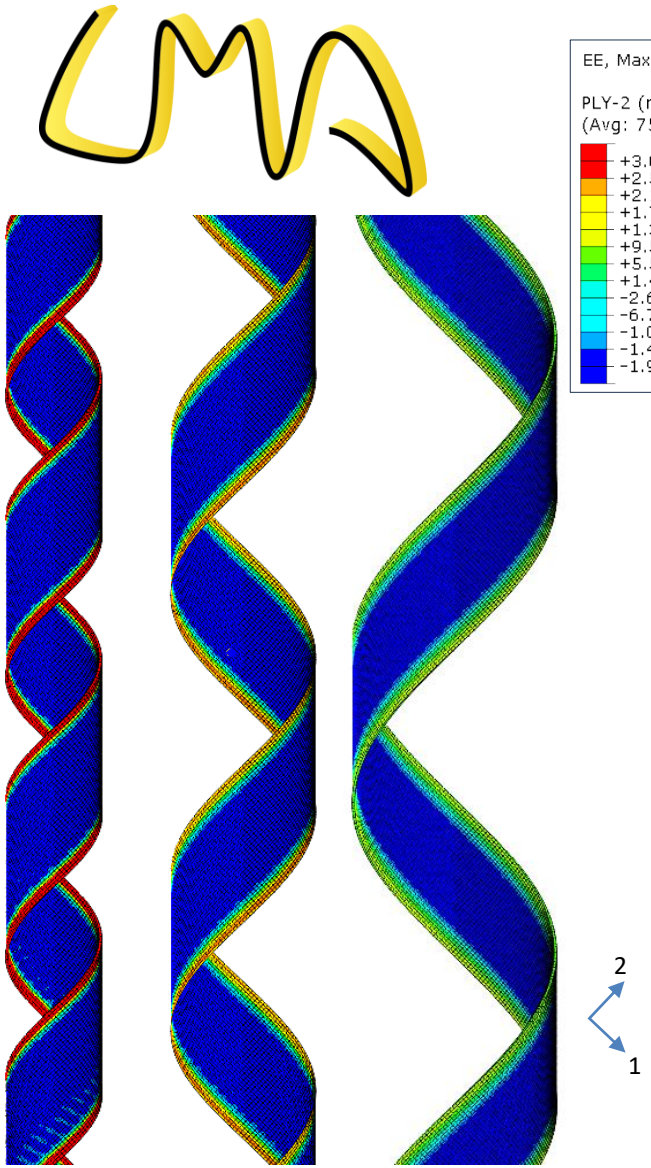
$\alpha = 30°$ $\alpha = 45°$ $\alpha = 60°$

- $+ \nearrow \alpha \Rightarrow$
  - $+ EE_{11}$ tends to be tensile
  - $+ EE_{22}$ is compressive
- Maximum tensile strain for $\alpha = 30°$: $\varepsilon_{max} = 0{,}27\ \%$

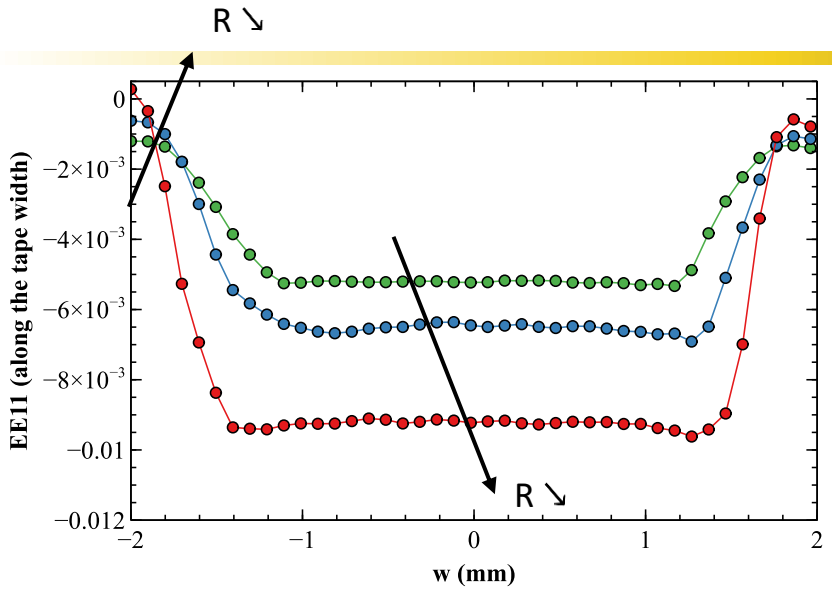
$R = 2{,}5$ mm, $F = 15$ N, $w = 4$ mm

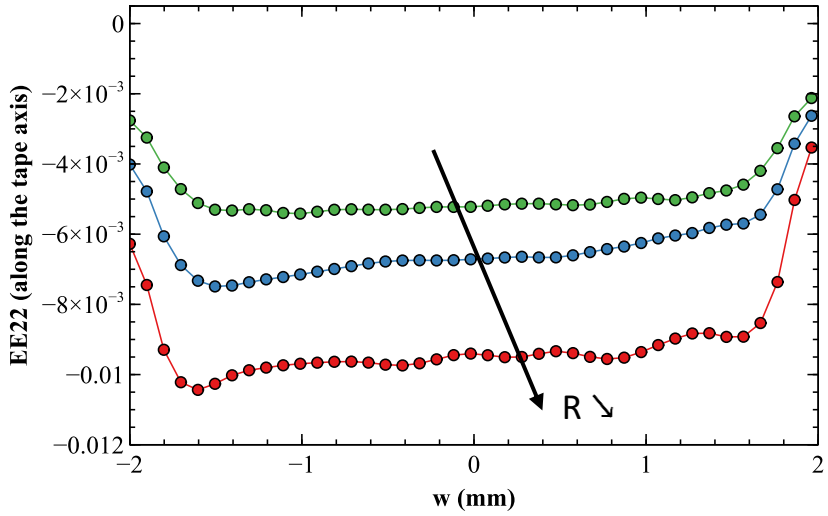
EE = Elastic strain in the ReBCO layer

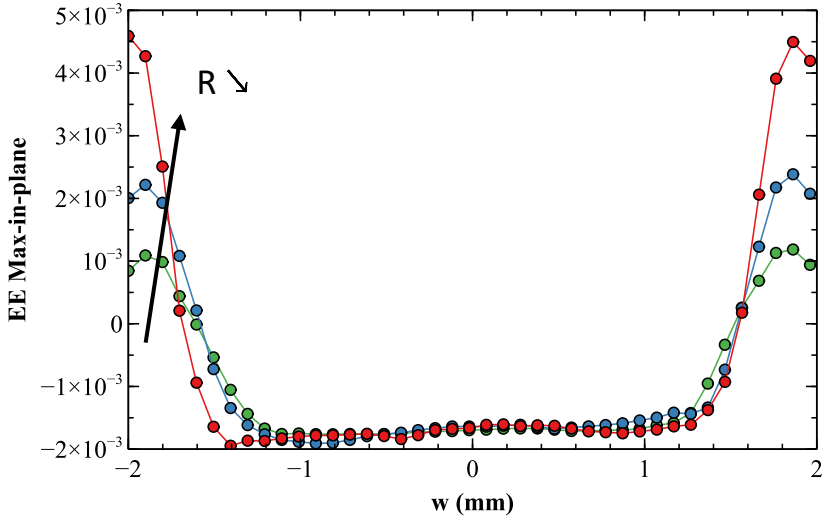
Core radius



$R = 1{,}6$ mm $R = 2{,}5$ mm $R = 3{,}5$ mm







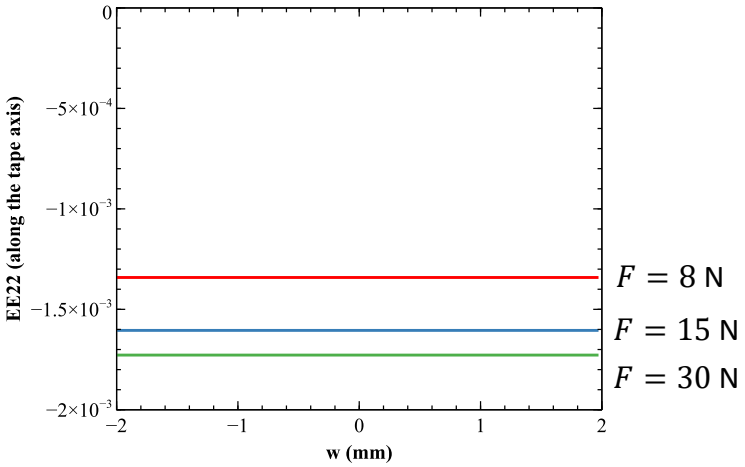
$R = 1{,}6$ mm $R = 2{,}5$ mm $R = 3{,}5$ mm

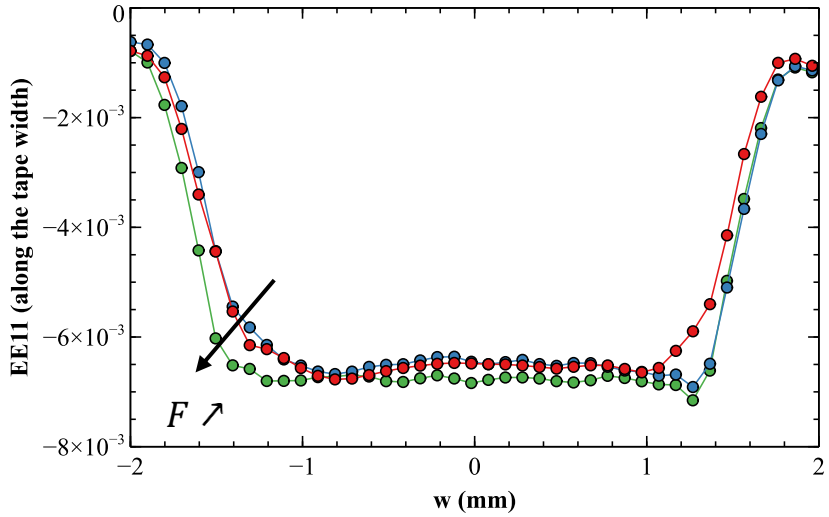
- $+ \nearrow R \Rightarrow$
  - $+ EE_{11}$ tends to be tensile at the center but there is an inversion at the edges
  - $+ EE_{22}$ tends to be tensile
- Maximum tensile strain for R $= 1{,}6$ mm: $\varepsilon_{max} = 0,46\%$

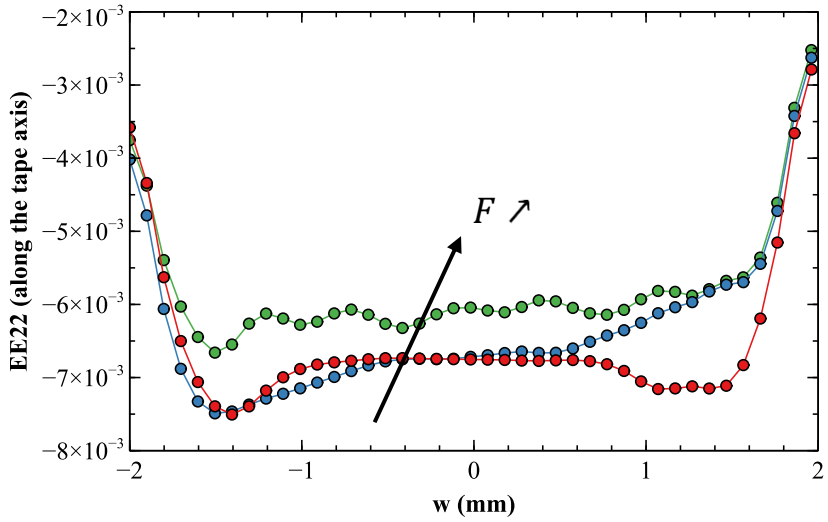
$\alpha = 45$ °, $F = 15$ N, $w = 4$ mm

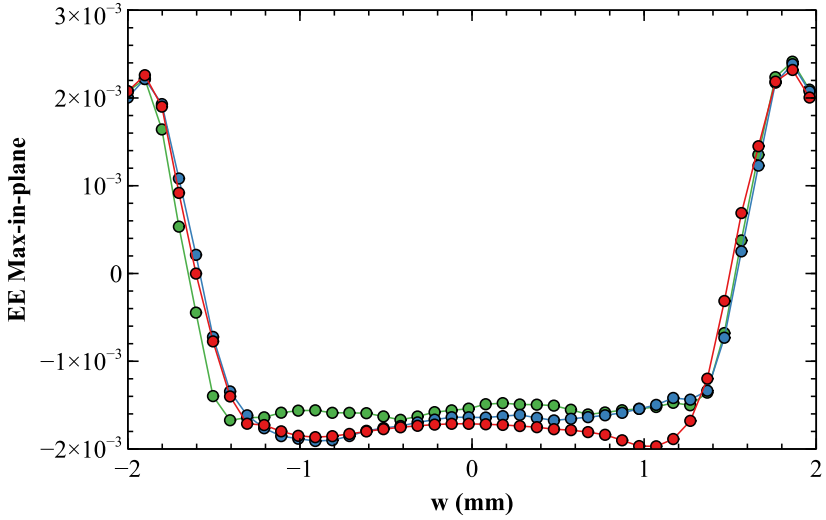
Winding tension

Step 4 – after applying winding tension







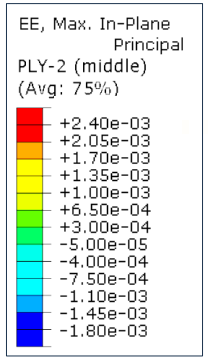


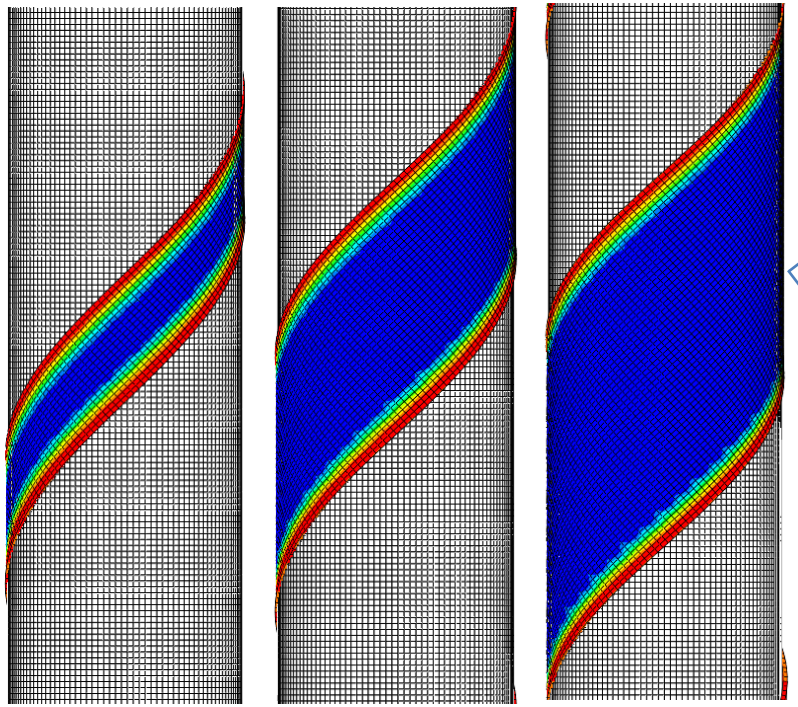
$F = 8$ N $F = 15$ N $F = 30$ N

- $+ \nearrow F \Rightarrow$
  - EE_{11} : no real influence
  - + the plateau value of $EE_{22} \nearrow$
- No influence on the value of the maximum tensile strain

EE = Elastic strain in the ReBCO layer

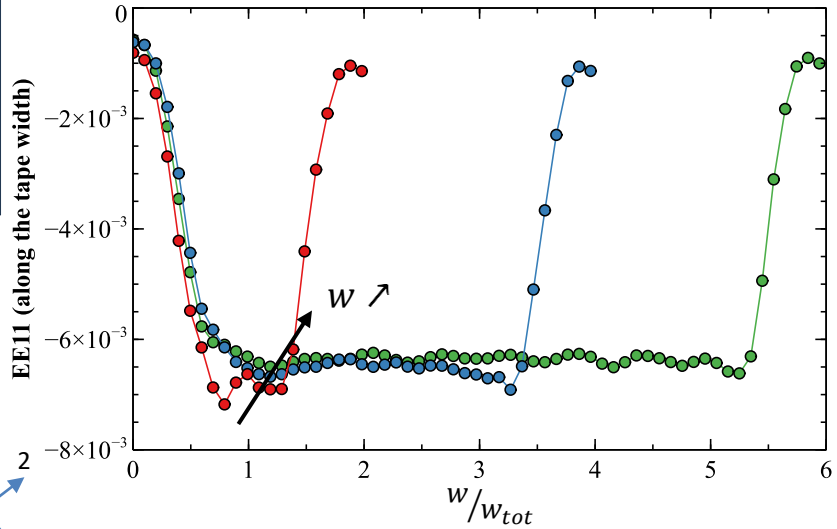
Tape width

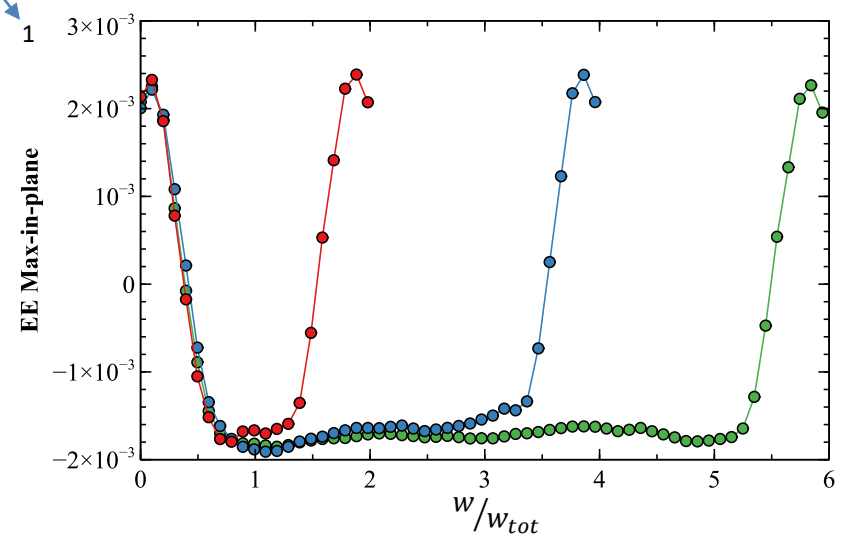


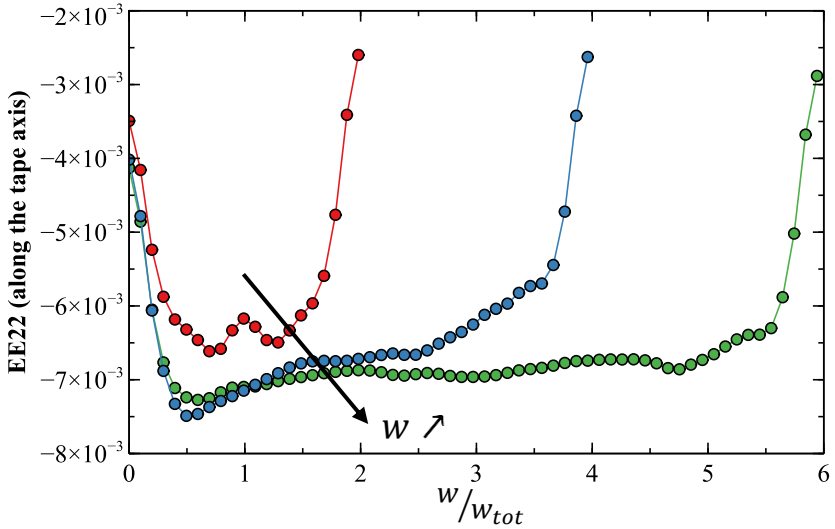


$w = 2$ mm $w = 4$ mm $w = 6$ mm

$\alpha = 45\,°, R = 2{,}5$ mm, $F = 15$ N



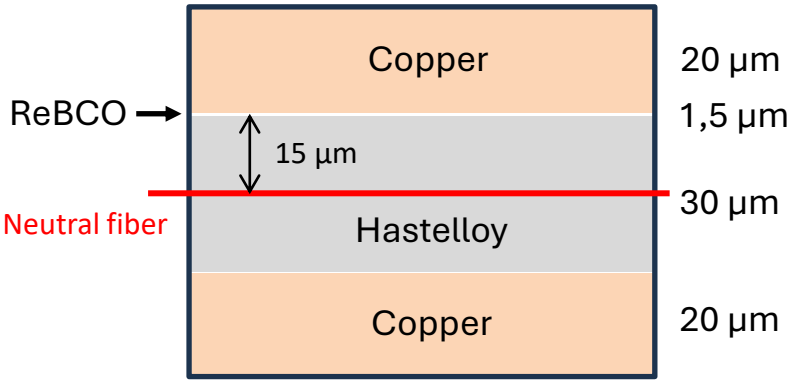


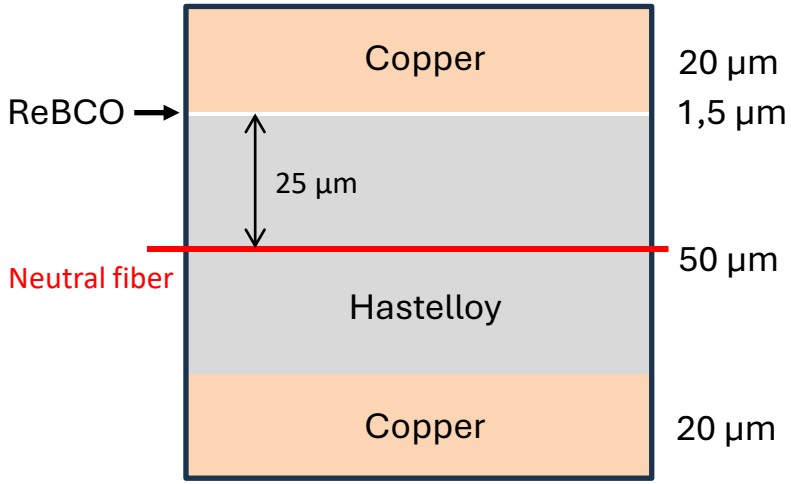


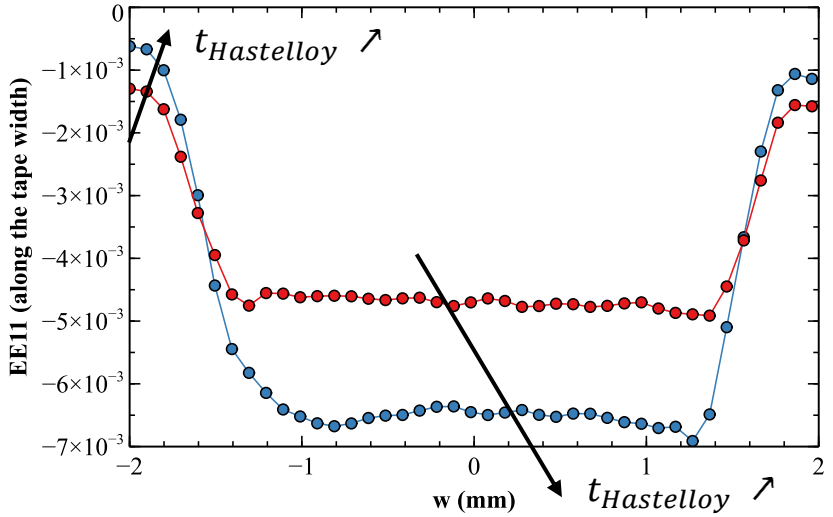
$w = 2$ mm $w = 4$ mm $w = 6$ mm

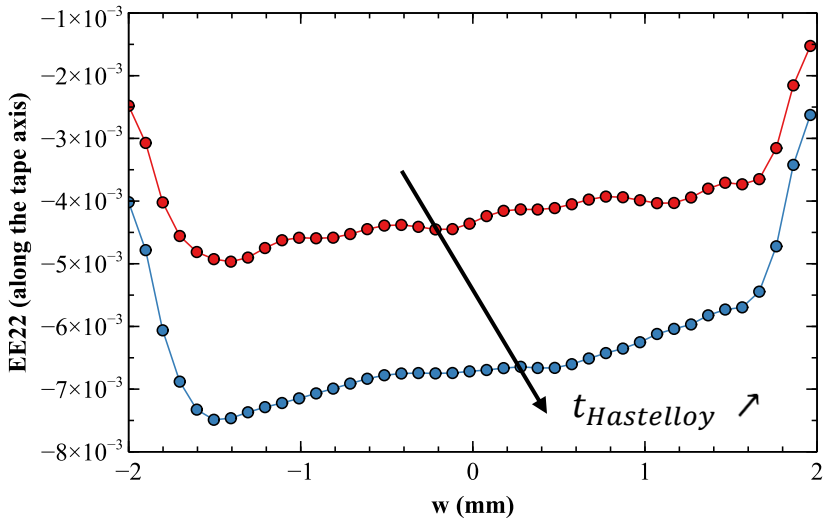
- $+ \nearrow w \Rightarrow$ EE_{11} : slight increase
  $+ EE_{22}$ is compressive
- No influence on the value of the maximum tensile strain

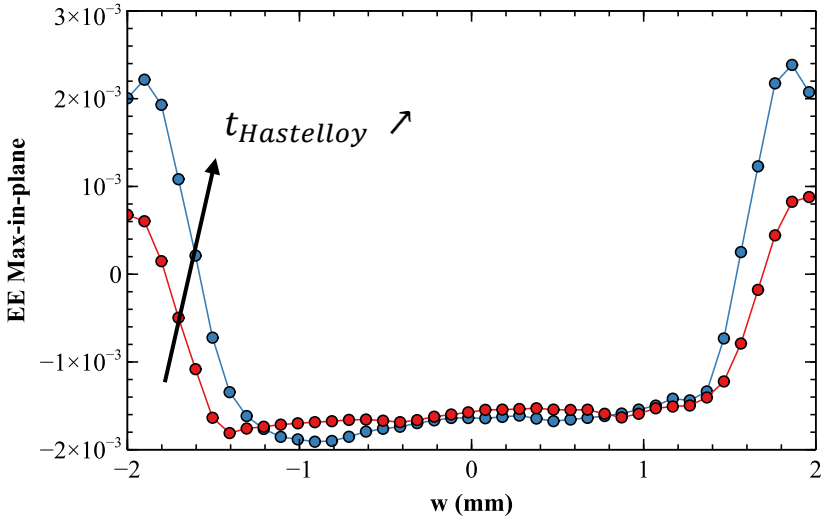
Hastelloy thickness











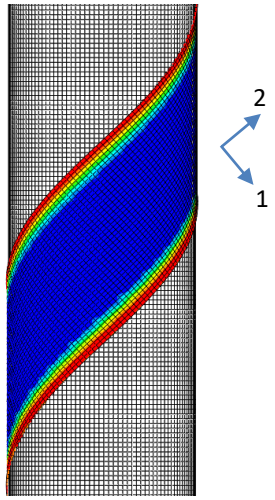
$t_{Hastelloy} = 30$ µm $t_{Hastelloy} = 50$ µm

- $+ \nearrow R \Rightarrow$
  - $+EE_{11}$ is compressive at the center but there is an inversion at the edges
  - $+EE_{22}$ is compressive
- Maximum tensile strain for $t_{Hastelloy} = 50$ µm: $\varepsilon_{max} = 0,23\%$

Conclusions & Perspectives

Summary

Variation during an increase of the parameter	Strain along tape width EE_{11}	Strain along tape axis EE_{22}	Maximum tensile train
α	↗	↘	Small α
R	↗ at the center / ↘ at the edge	↗	Small R
F	–	↗	–
w	↘	↘	–
$t_{Hastelloy}$	↘ at the center / ↗ at the edge	↘	Big $t_{Hastelloy}$



Perspectives

Winding of one (or several) ReBCO tape(s) around a core → Mechanical loading of the CORC cable and decrease in temperature (T = 77 K) → Application of an electromagnetic force

- Study of the tape deflection and deformation in the gaps between different layers
- Validation of the multiple-tapes model
- Comparison with experiments that will be realized at CEA Cadarache (transversal compression or/and tensile test at 77 K)

Bibliography

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- Wang et al., 2022: *Prediction of strain, inter-layer interaction and critical current in CORC® wires under axial strain by T-A modeling*, Superconductor Science and Technology
- Yan et al., 2022: *Investigating the effect of transverse compressive loads on the electromagnetic performance of superconducting CORC® cables*, Superconductor Science and Technology

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Thank you for your attention !