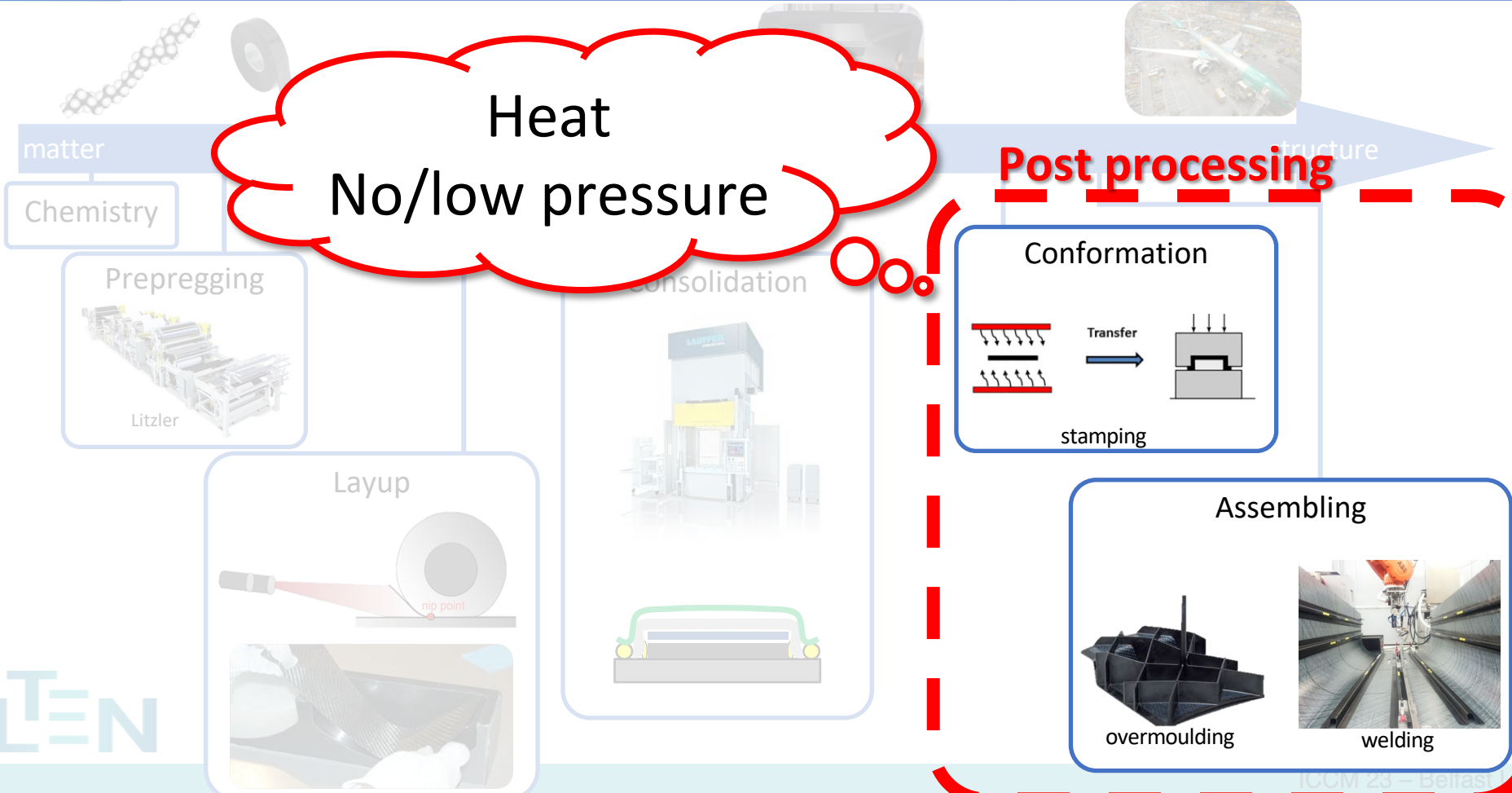


CHARACTERIZATION OF DRIVING MECHANISMS INVOLVED IN DECONSOLIDATION OF THERMOPLASTIC COMPOSITE LAMINATES

Luc Amedewovo, Arthur Levy, Laurent Orgeas, Basile de Parscau du Plessix, Steven Le Corre

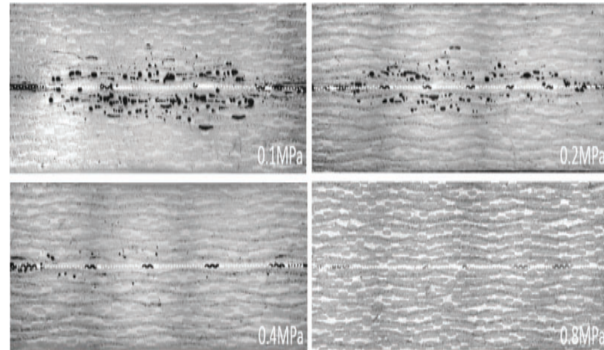
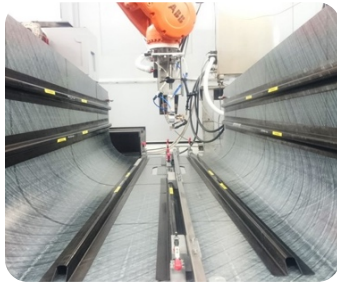
arthur.levy@univ-nantes.fr

TPC manufacturing steps



Deconsolidation

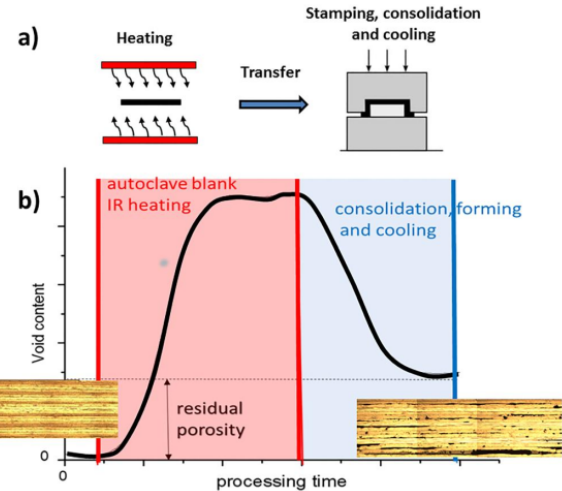
Welding



GF/PEI resistance welding

[Shi et al. 15]

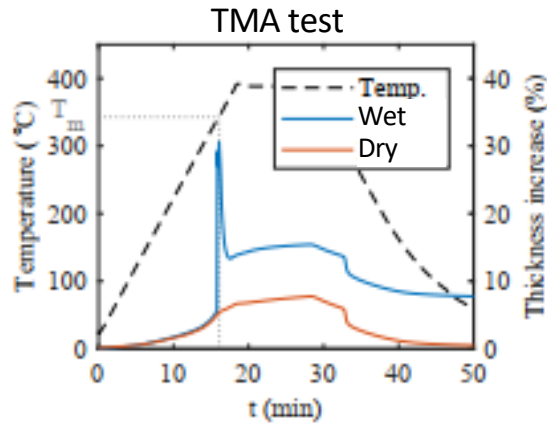
Thermo stamping



[Donnadei et al. 18]

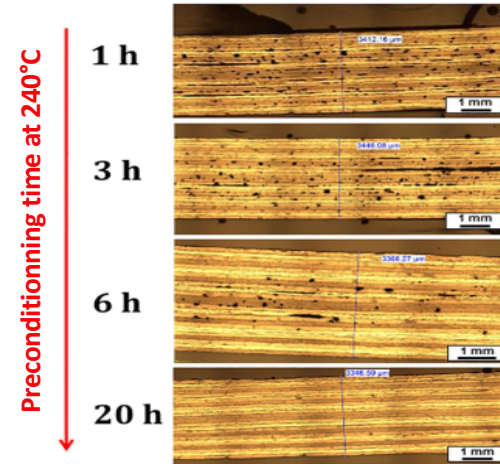
State of the art hypothesis

Moisture



[Slange et al. 18]

Residual stresses



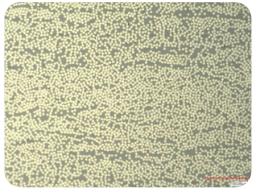
[Donadei et al 18]

Motivation

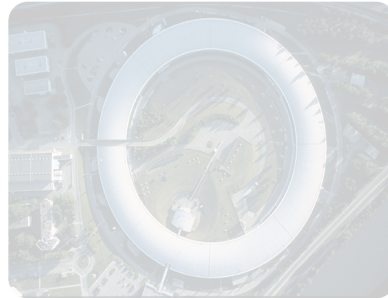
Understand the deconsolidation phenomenon,
need for characterization

Outlines

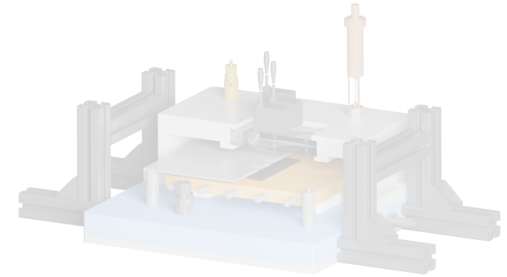
1 - Material



2 - Microstructural in-situ analysis



3 - Macroscopic parametric study



Laminate preparation

Material

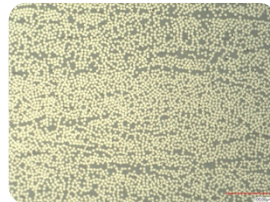
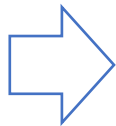
CF/PEKK (Toray Composites)
348 * 348 mm*2,90 mm
16 plies UD, 0°

Consolidation

- Press (40 bar)



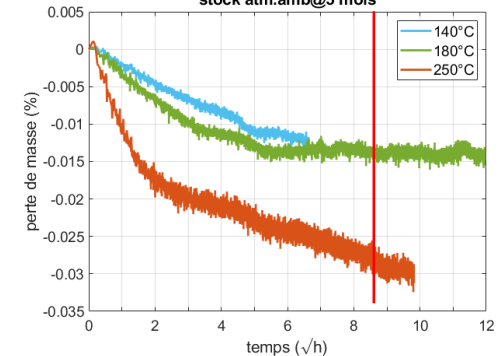
- Oven (VBO)



Pre-conditionning

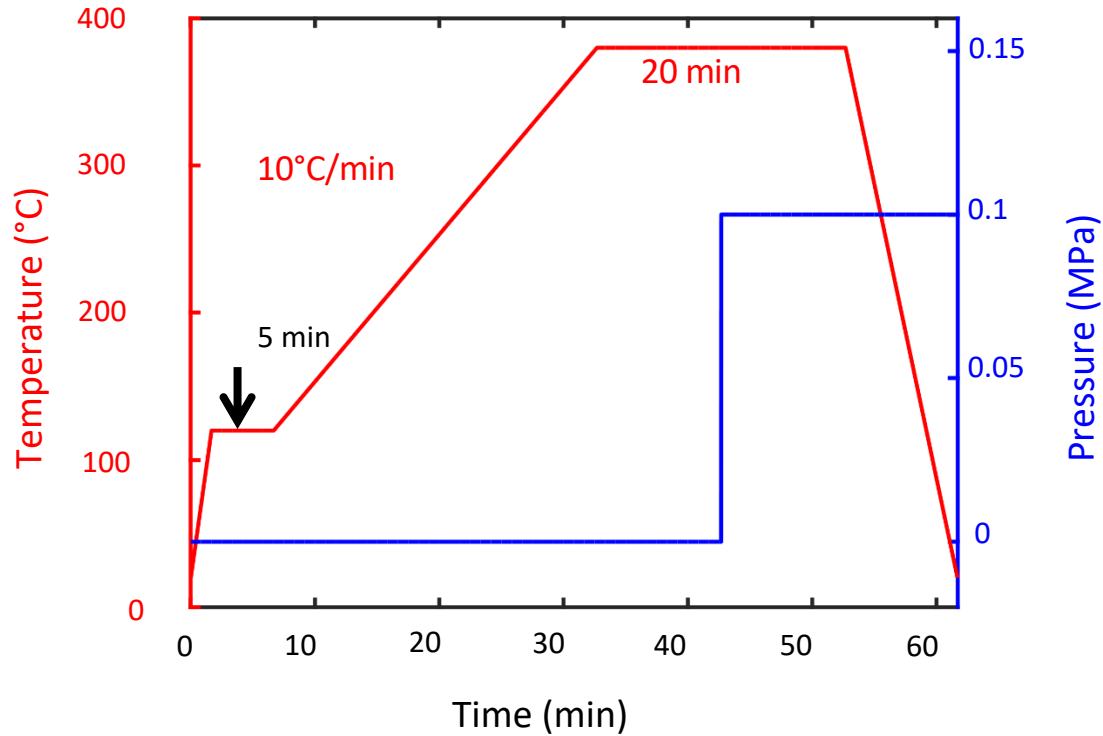
- Ambient storage
(for 5 months → 0.02 % H₂O)
- Water immersed
- Dried 180°C
- Annealed 250°C

courbe désorption sur des plaques de 80mm*80mm*16plis
stock atm.amb@5 mois



[Amedewovo et al 23b]

Deconsolidation cycle



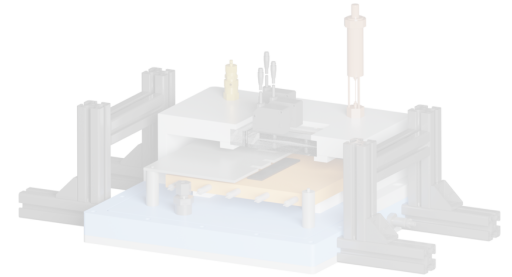
1 - Material



2 - Microstructural in-situ analysis



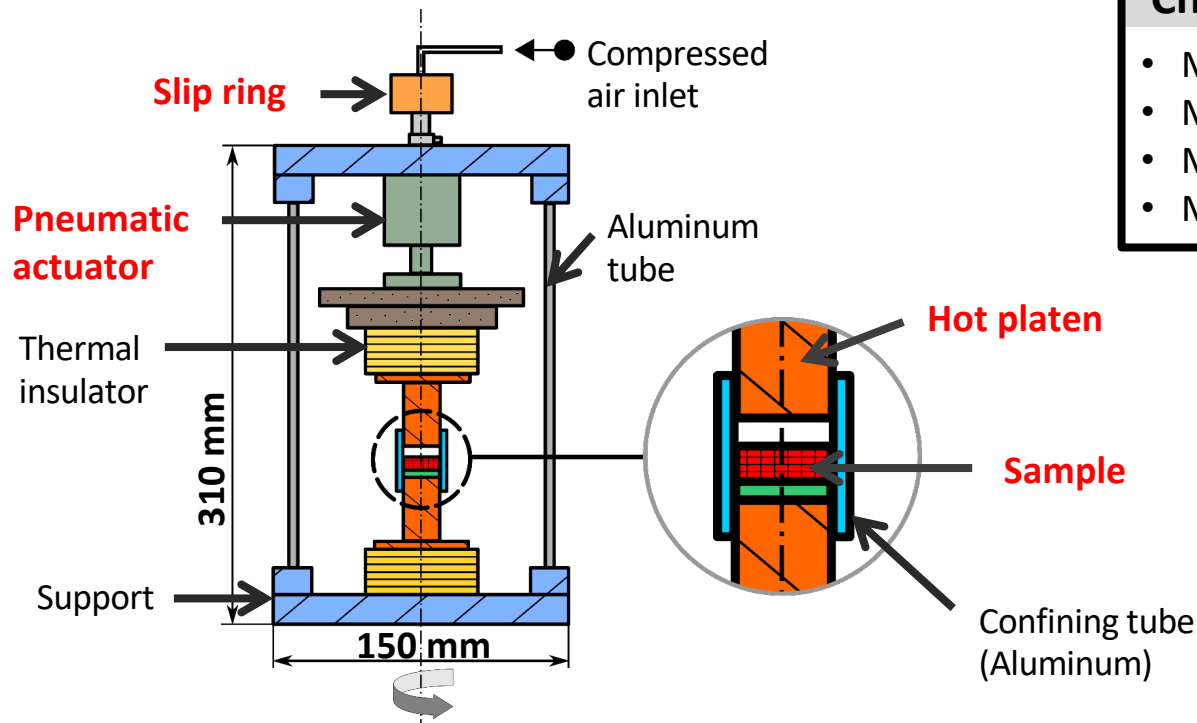
3 - Macroscopic parametric study



In situ Tomography Observation

Characteristics

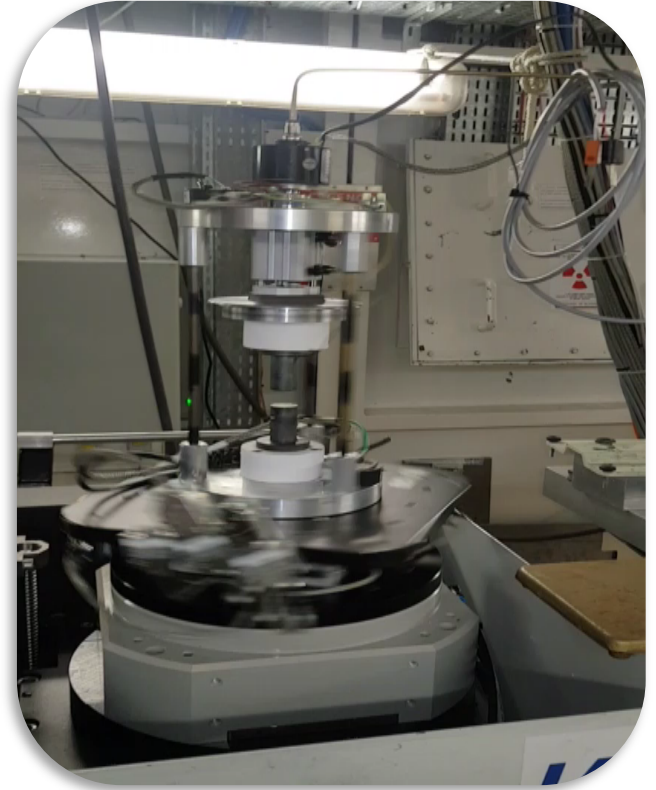
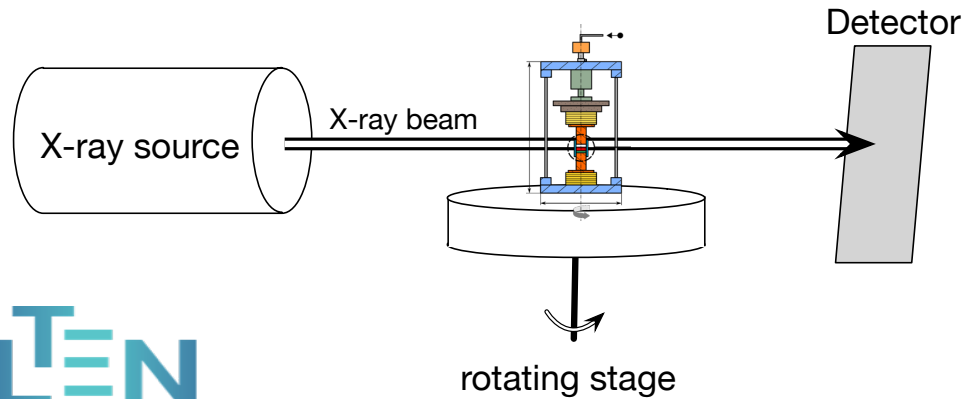
- Max temperature: **450°C**
- Max heating rate: **2°C/s**
- Max pressure: **1.2 MPa**
- Max sample diameter: **20 mm**



In the synchrotron

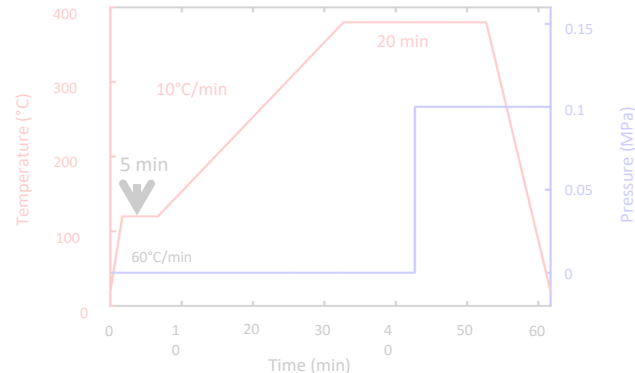


ID 19 - ESRF Grenoble



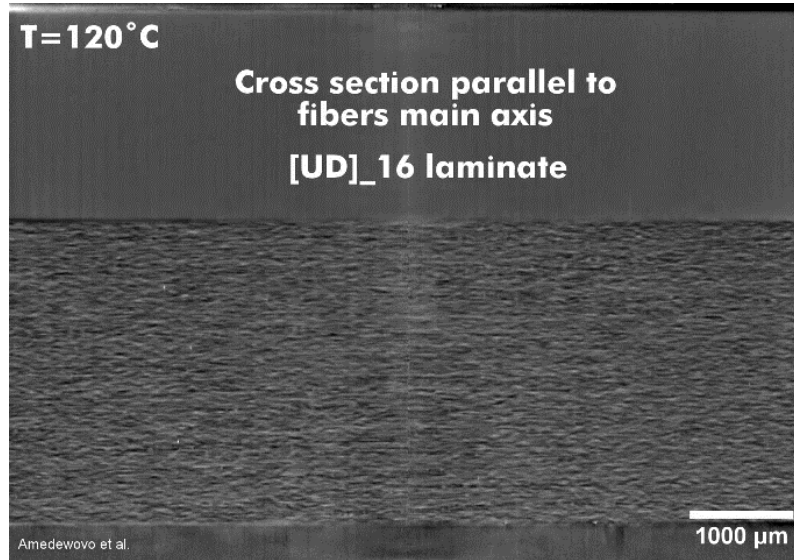
Test Matrix

#	Preconditioning	Stacking sequence	Heating type	Counter pressure
1	Water immersed (WI) 3 months @ 0.1 wt. %H ₂ O	UD	Bi-lateral	-
2	Dried – 72h@180°C	UD	Bi-lateral	-
3	WI	CP	Bi-lateral	0.1 MPa
4	WI	UD	Uni-lateral	0.05 MPa

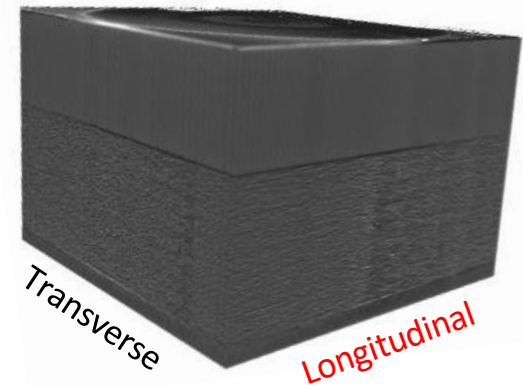


3D fields

- Test 2: Dried / UD / Bi-lateral

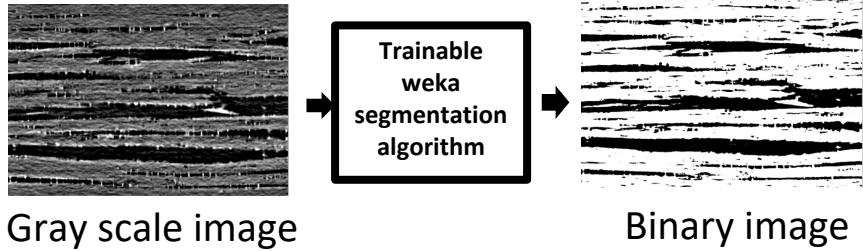


3D grey level image

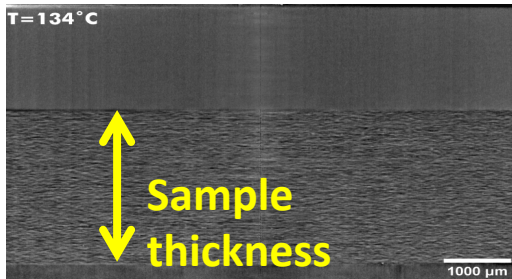


Processing

Porosity content

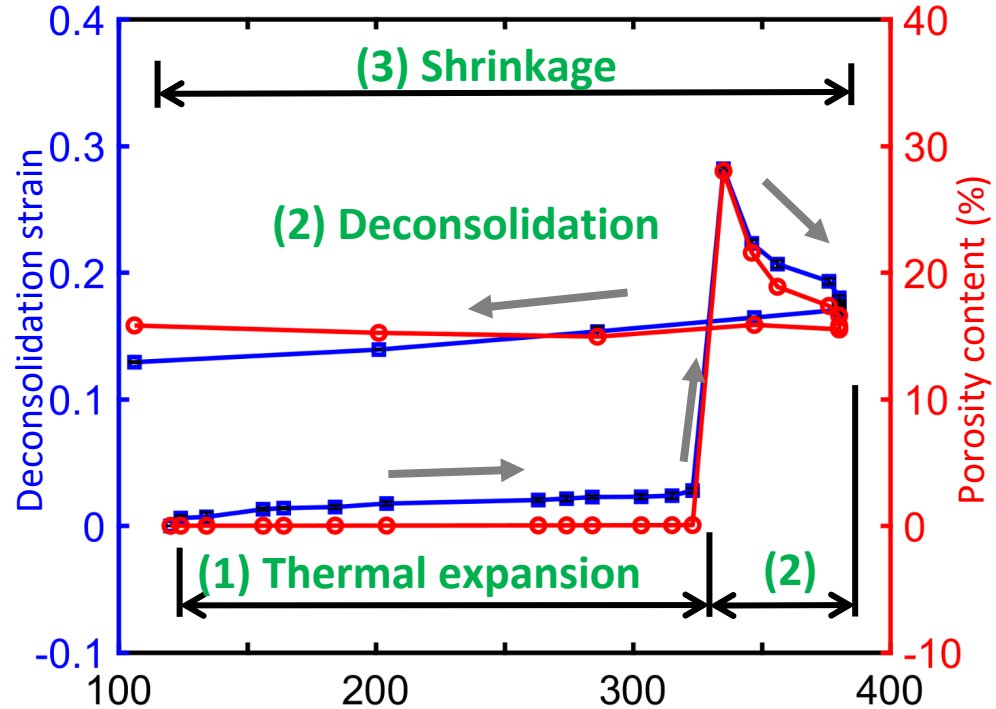


Global strain



$$\varepsilon_D = \ln\left(\frac{\text{current thickness}}{\text{initial thickness}}\right)$$

- Test 2: Dried / UD / Bi-lateral



Processing

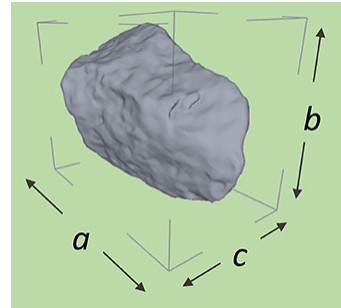
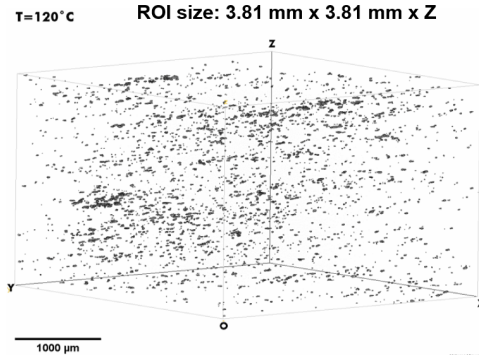
Pore sizes

1. Pore fitting with Oriented Bounding Box (OBB)

pore length = a

2. Pore classification by length

3. **Volume fraction** = $\frac{\text{Pore class volume}}{\text{Total pore volume}} \times 100$



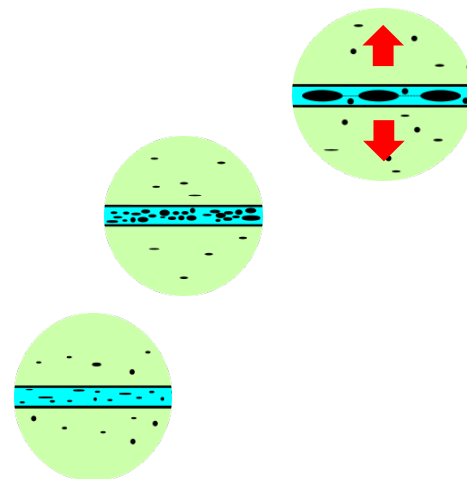
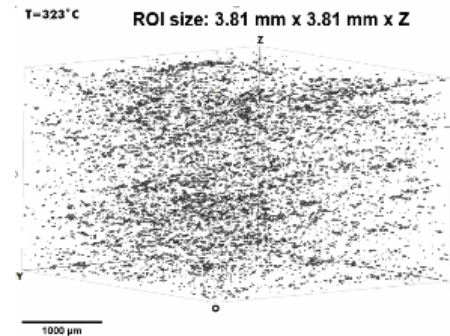
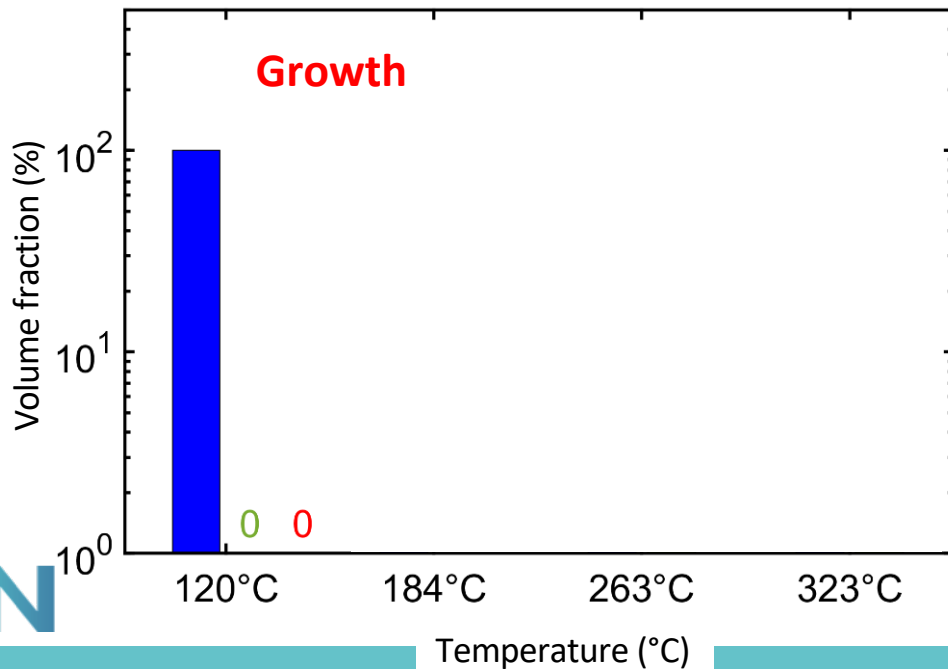
- Length ≤ 0.1 mm
- 0.1 < Length ≤ 1 mm
- Length > 1 mm

Pore growth and splitting

Test 2: Dried / UD / Bi-lateral

- Length ≤ 0.1 mm
- $0.1 < \text{Length} \leq 1$ mm
- Length > 1 mm

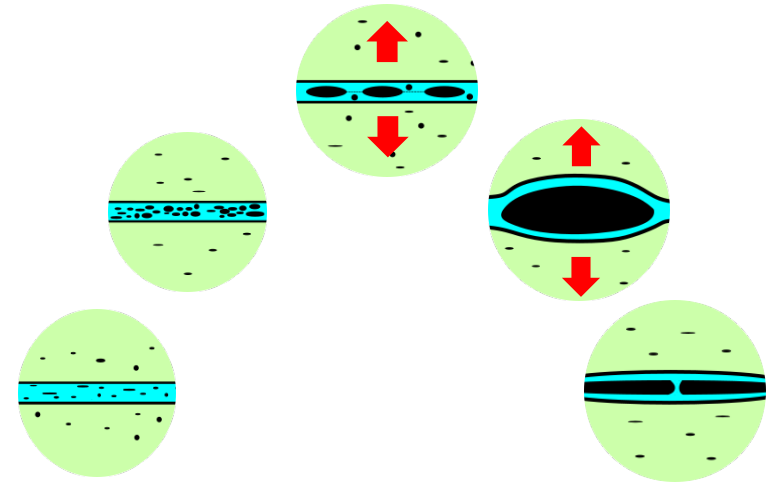
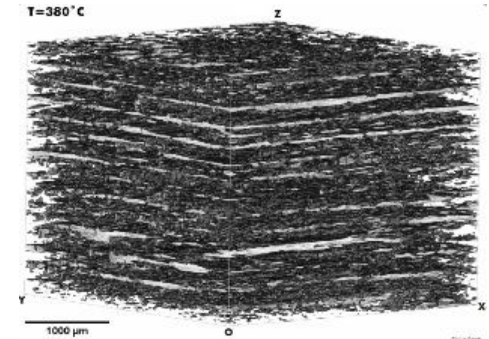
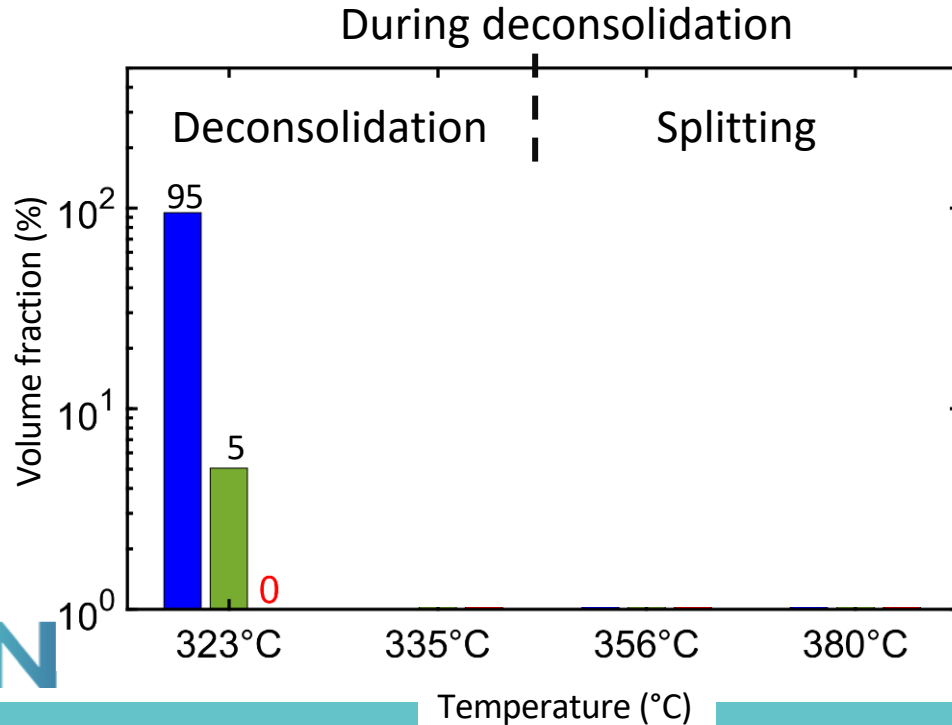
Before deconsolidation



Pore growth and splitting

Test 2: Dried / UD / Bi-lateral

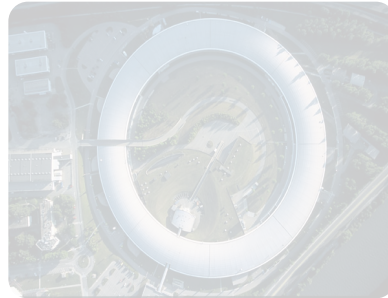
- Length ≤ 0.1 mm
- $0.1 < \text{Length} \leq 1$ mm
- Length > 1 mm



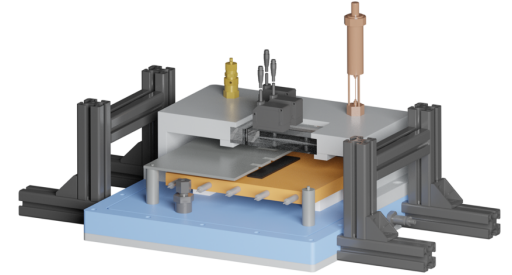
1 - Material



2 - Microstructural in-situ analysis

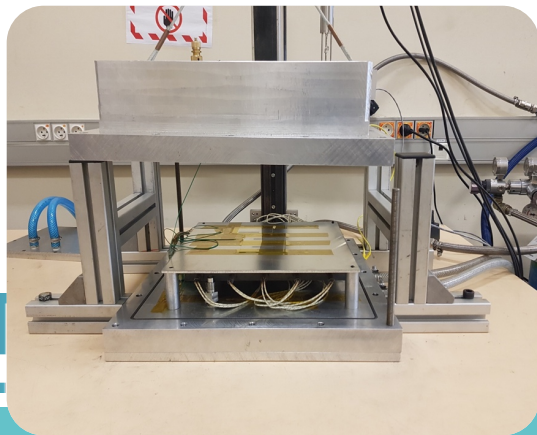
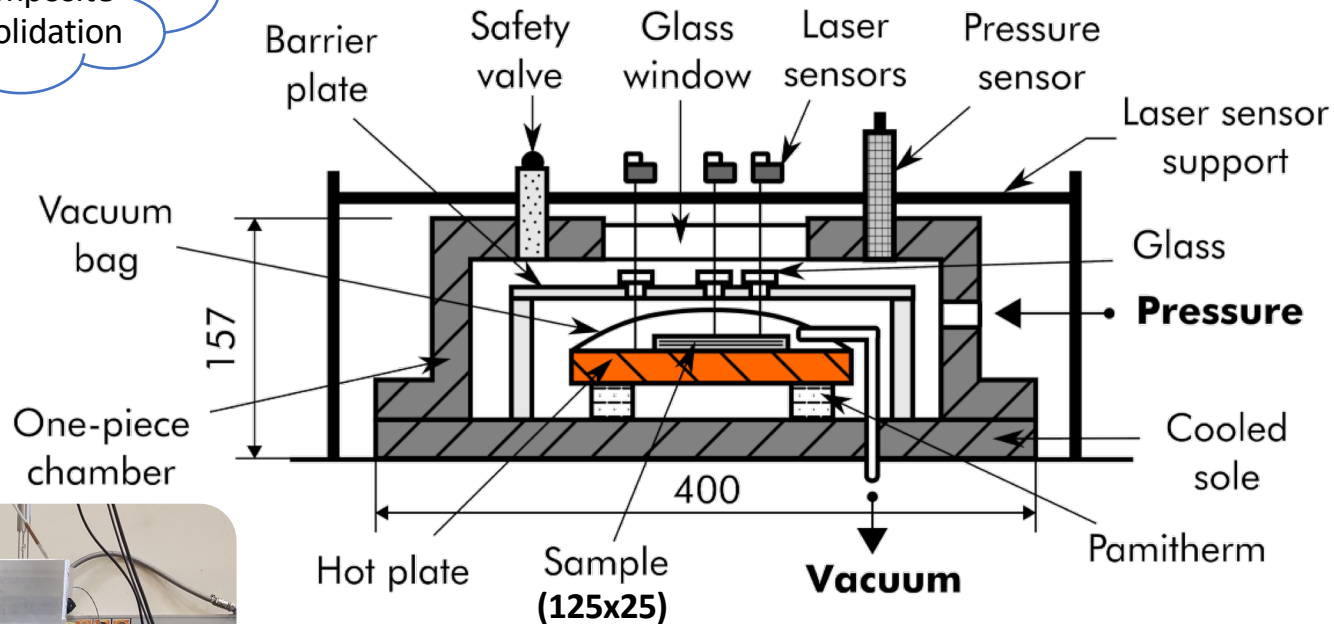


3 - Macroscopic parametric study



Continuous in-situ
COmposite
DEConsolidation

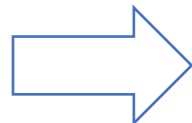
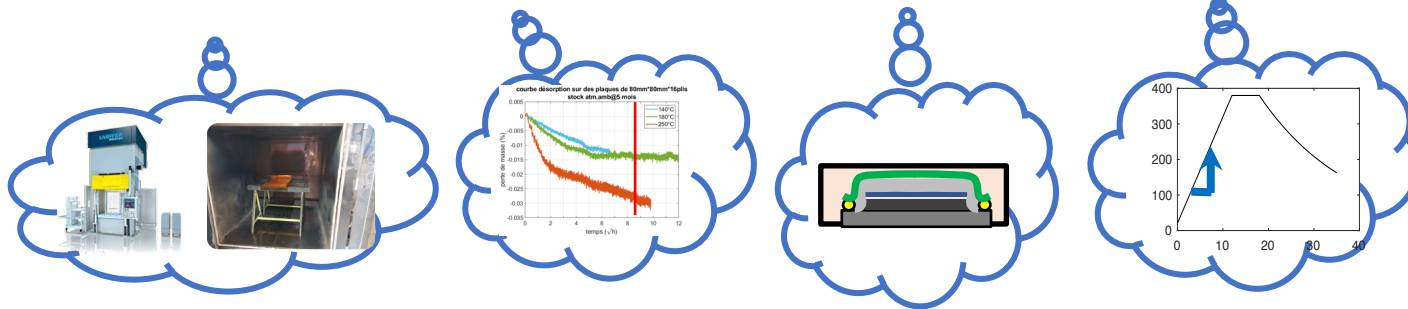
CODEC bench



Up to 450°C
Up to 10 bars
Up to 60°C/min

Test matrix

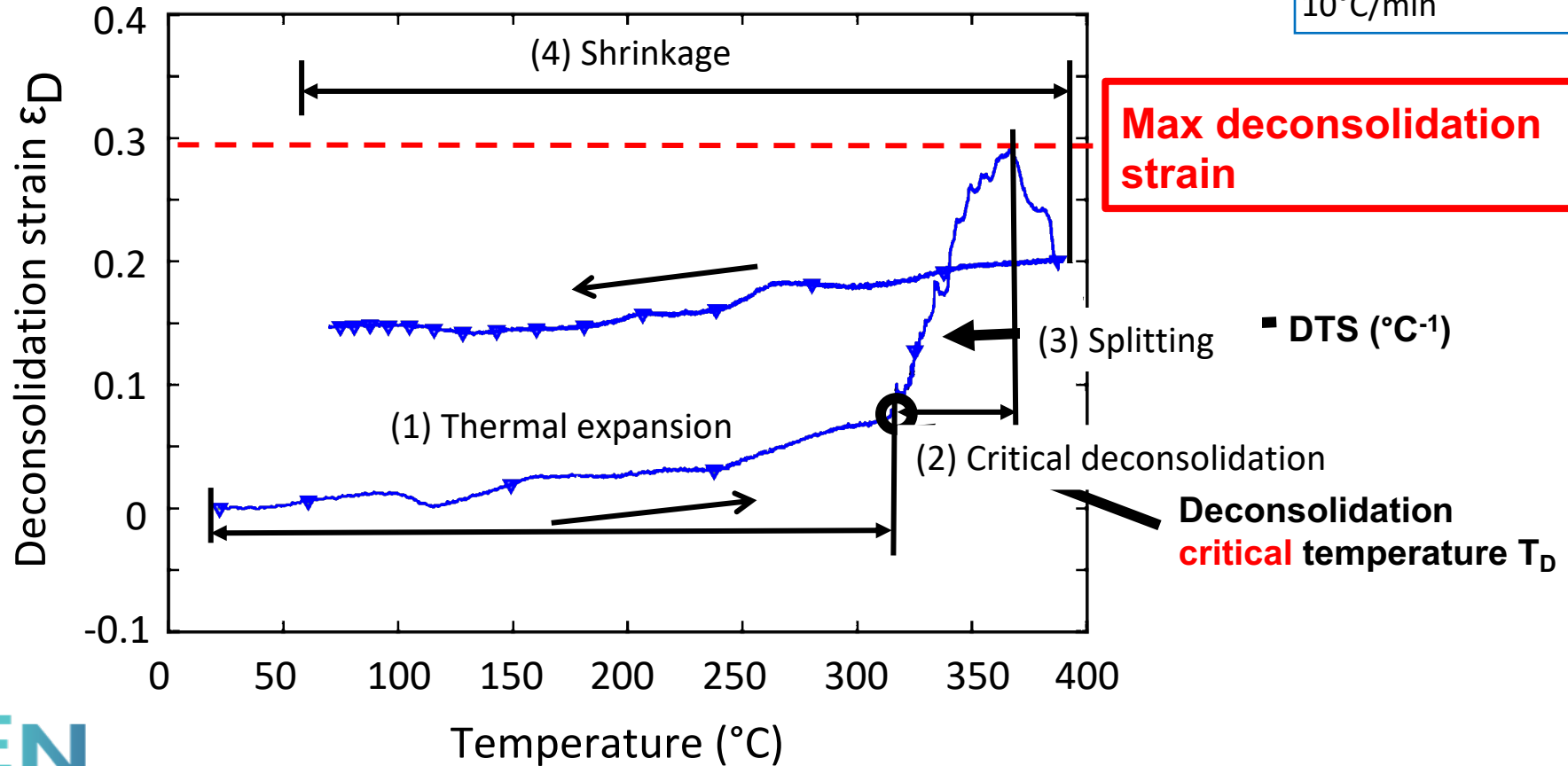
Initial laminate		Deconsolidation	
Process	Conditionning	Counterpressure	Heating rate
HP	Dried	No pressure	5° C/min
VB	Annealed	1 bar	10° C/min
	Ambiant storage	3 bar	60° C/min
	Immersed	5 bar	



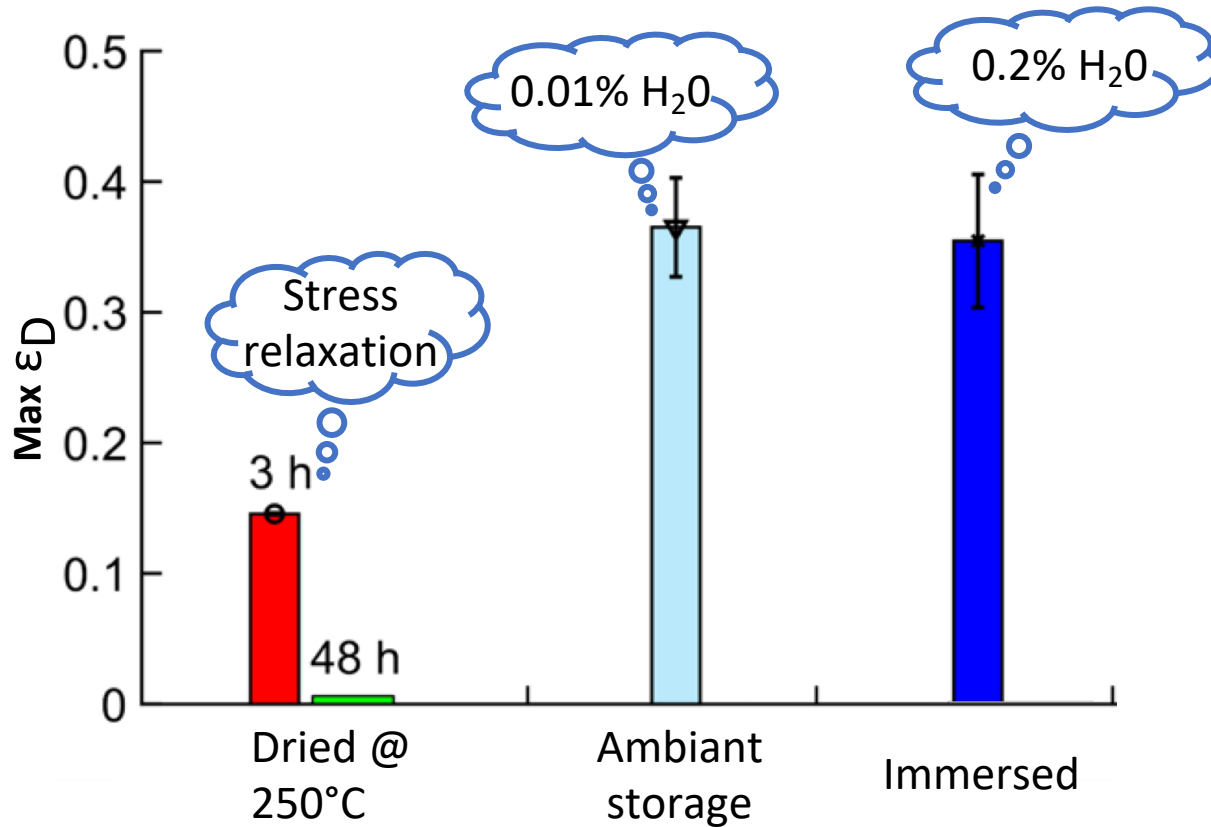
200 tests

Deconsolidation graph

Press consolidated,
Dried, no pressure,
10°C/min



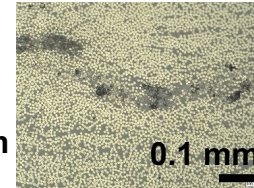
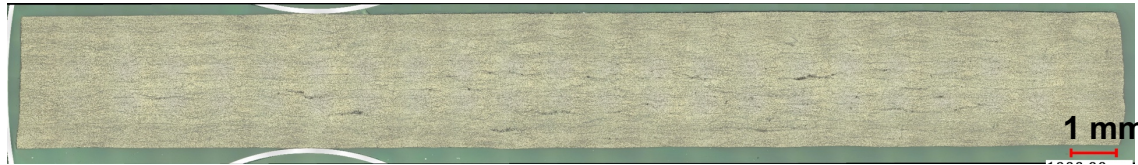
Maximum deconsolidation strain



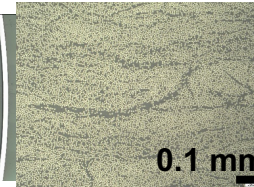
UD, HP
Heating rate = 10°C/min
No counter pressure

After experiments micrographs

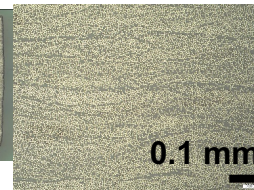
UD- HP - **Dried (DS) 1 week@180°C**



UD - HP - **Annealed (AN) 48h@250°C**



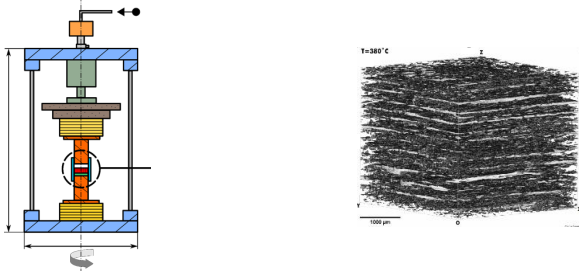
UD - HP - **Annealed (AN) 48h@250°C +
Rehumidifying 1 week : 0.04 wt. %H₂O**



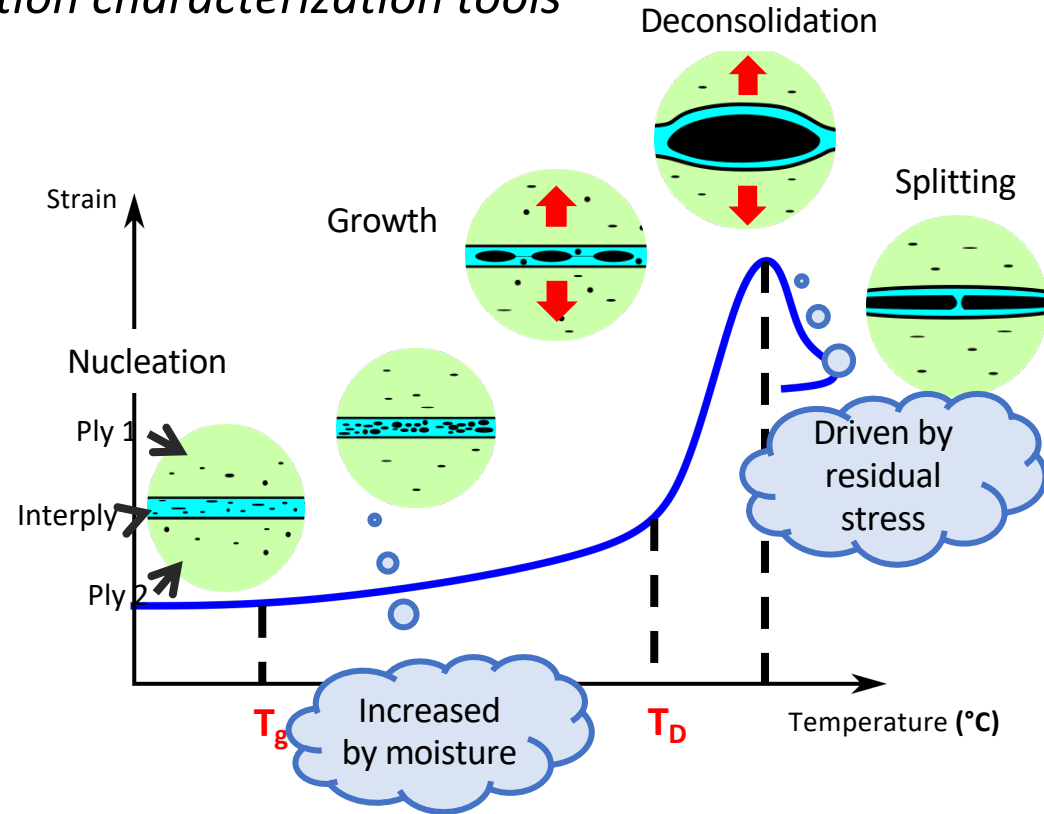
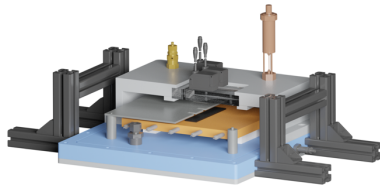
Conclusions

Thermoplastic laminates deconsolidation characterization tools

Microstructural in-situ analysis



Macroscopic parametric study



Acknowledgement

- PERFORM project led by IRT Jules Verne
- PERFORM partners Airbus, Safran, Latecoere, Stelia Aerospace, Clayens NP, Naval Group and Faurecia.
- Arnaud Arrivé and Julien Aubril : CODEC bench development and fabrication
- Nicolas Lefevre for the Synchrotron bench development
- AFM for co-funding my travel



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