LABORATOIRE DE THERMIQUE ET ÉNERGIE DE NANTES

CHARACTERIZATION OF DRIVING MECHANISMS INVOLVED IN DECONSOLIDATION OF THERMOPLASTIC COMPOSITE LAMINATES

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Jul. 2023

ICCM 23 – Belfast UK

Today's challenges

Increase part complexity

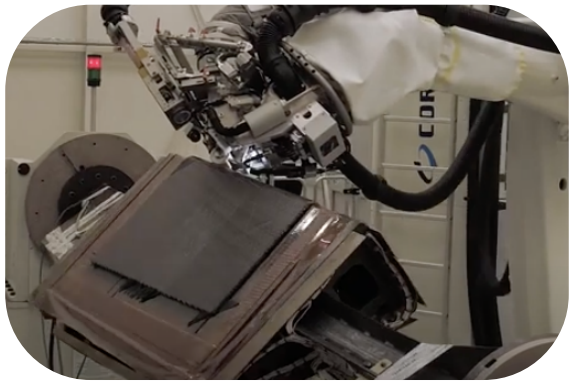
Pylone MATCH project

Boeing assembly line

- Intricate / thick parts
- Large parts
- Assembly

Cheap / sustainable

www.sabca.be



- Fast and efficient cycles
- Out-of-autoclave
- Defect free

TP composites

TPC manufacturing steps

Heat
No/low pressure

structure

Prepregging

Litzler

Consolidation

Layup

nip point

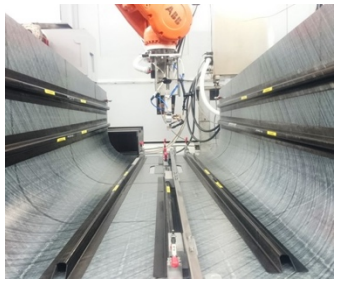
Post processing

Conformation

stamping

Assembling

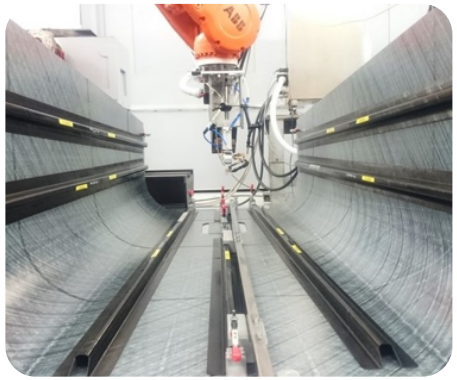
overmoulding

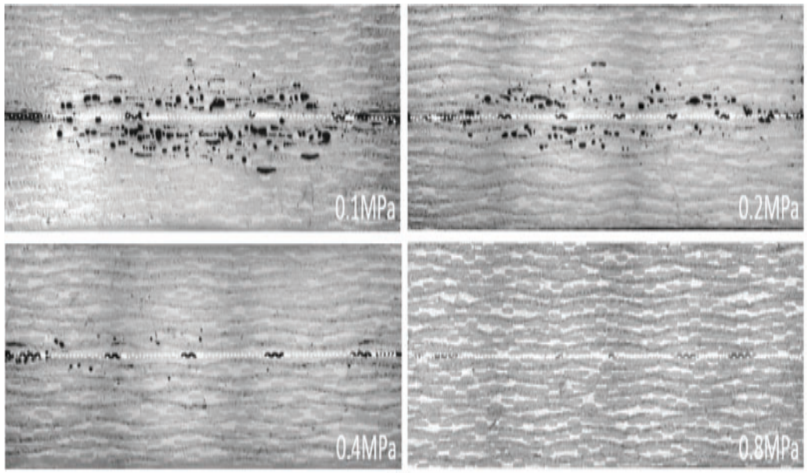


welding

Deconsolidation

Welding

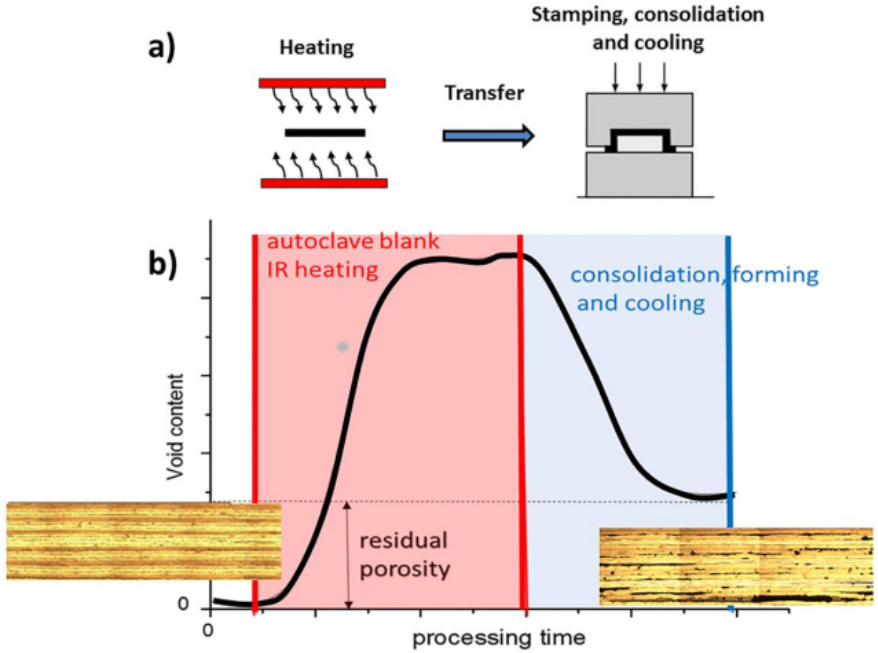




GF/PEI resistance welding

[Shi et al. 15]

Thermo stamping

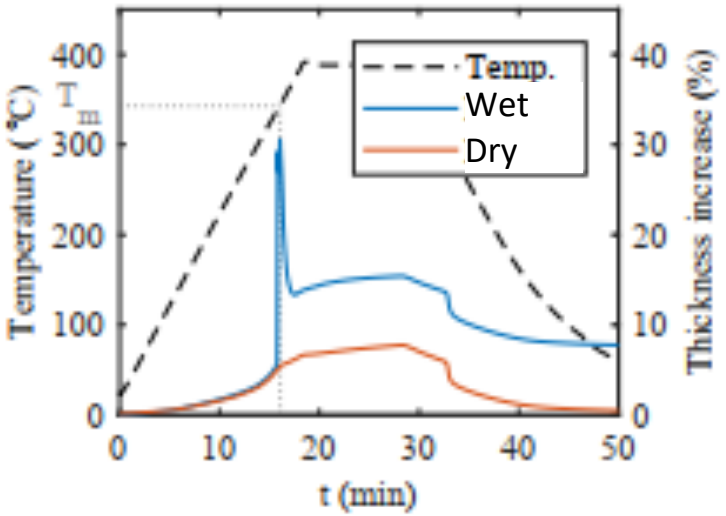


[Donnadei et al. 18]

State of the art hypothesis

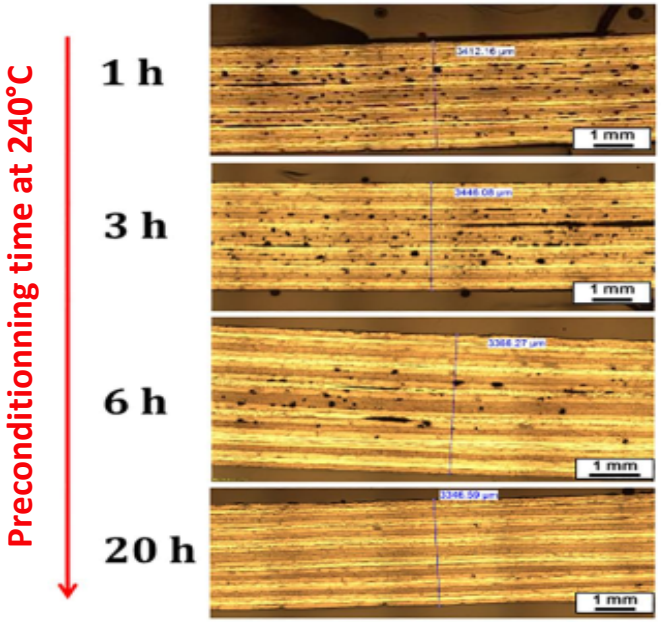
Moisture

TMA test



[Slange et al. 18]

Thermo-mechanics



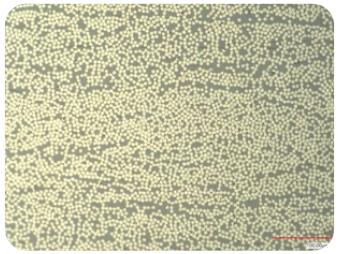
[Donadei et al 18]

Motivation

Understand the deconsolidation phenomenon,
need for characterization

Outlines

1 - Material



2 - Microstructural in-situ analysis

3 - Macroscopic parametric study

Laminate preparation

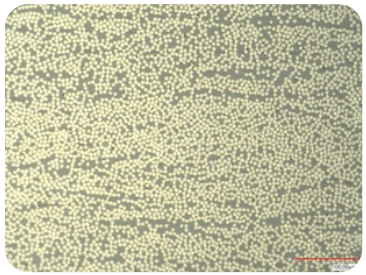
Material

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

Consolidation

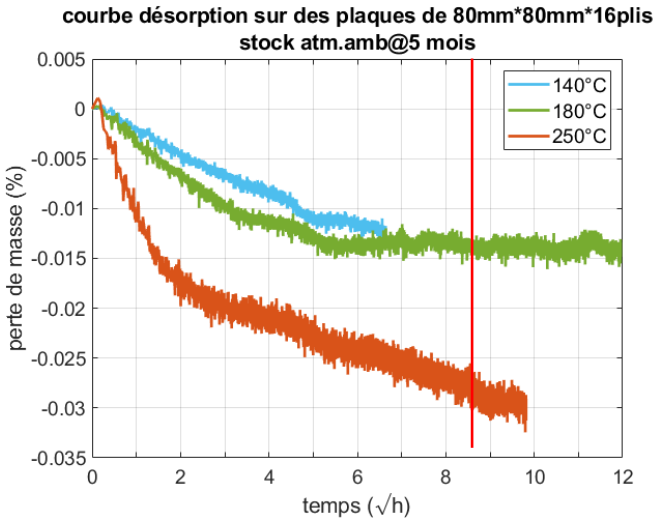
- Press (40 bar)

- Oven (VBO)



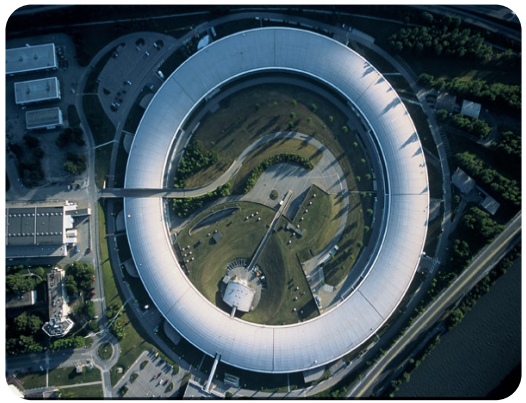
Pre-conditionning

- Drying 180°C / 72h
- Ambiant storage
  (for 5 months → 0.013 % H2O)



1 - Material

2 - Microstructural in-situ analysis

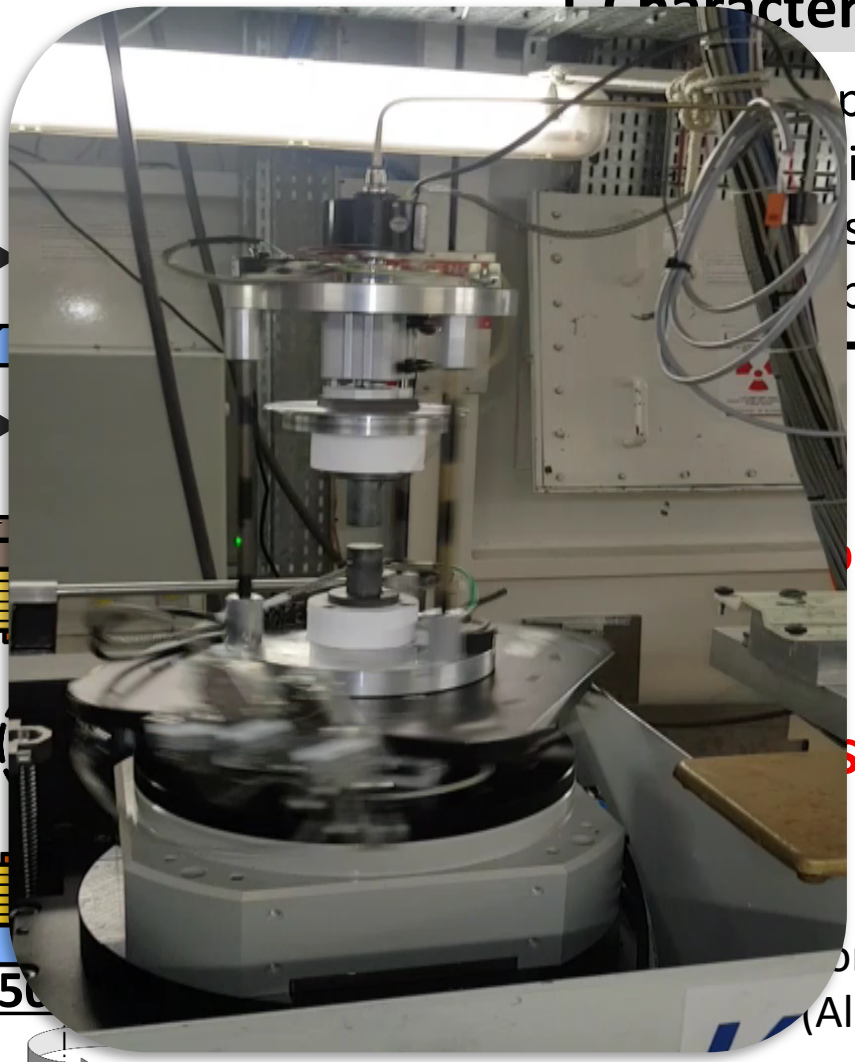


3 - Macroscopic parametric study

In situ Tomography Observation

Characteristics

- perature: **450°C**
- ing rate: **2°C/min**
- sure: **1.2 MPa**
- ple diameter: **20 mm**

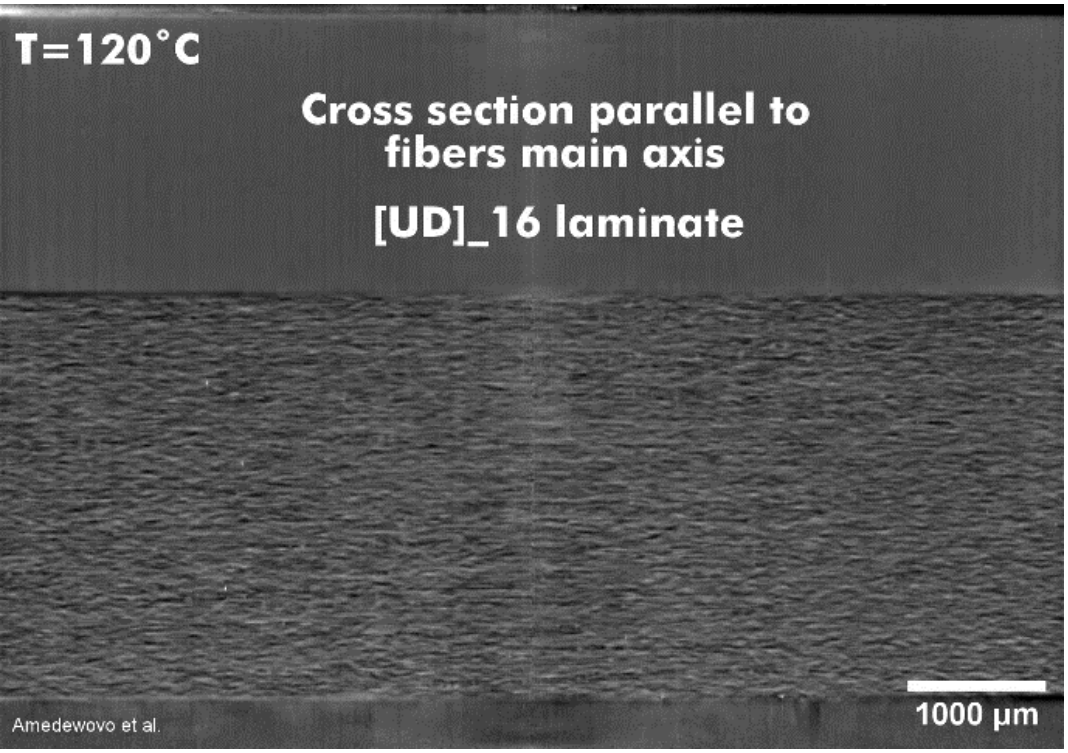


Test Matrix

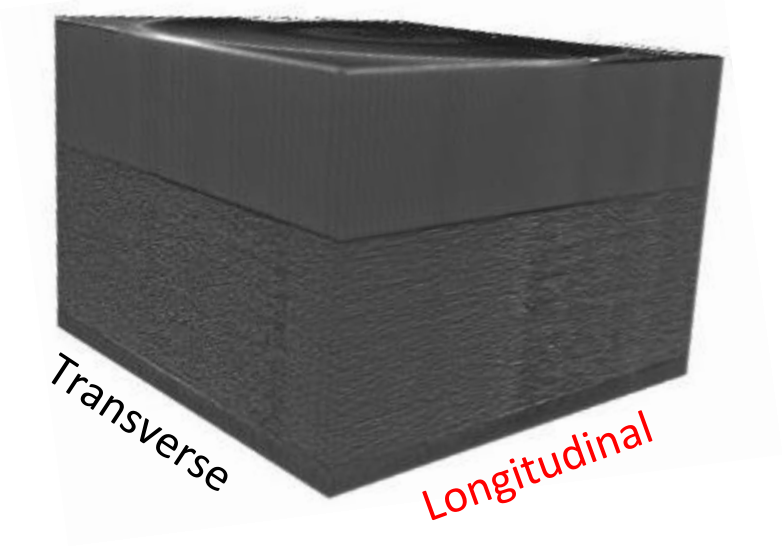
#	Preconditioning	Stacking sequence	Heating type	Counter pressure
1	**Water immersed (WI)** 3 months @ **0.1 wt. %H2O**	UD	Bi-lateral	-
2	**Dried – 72h@180°C**	UD	Bi-lateral	-
3	WI	**CP**	Bi-lateral	**0.1 MPa**
4	WI	UD	**Uni-lateral**	**0.05 MPa**

3D fields

- Test **2**: Dried / UD / Bi-lateral

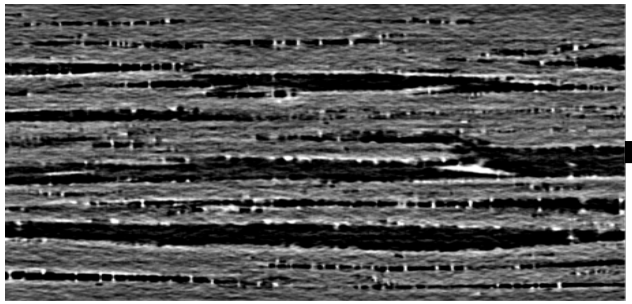


3D grey level image

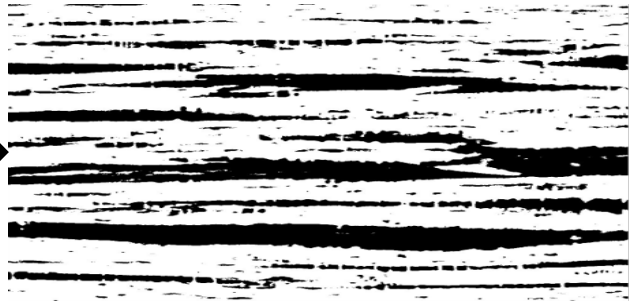


Processing

Porosity content



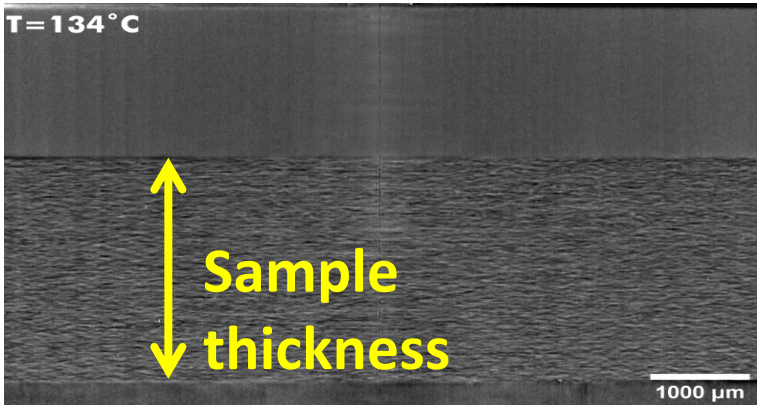
Trainable weka segmentation algorithm



Gray scale image

Binary image

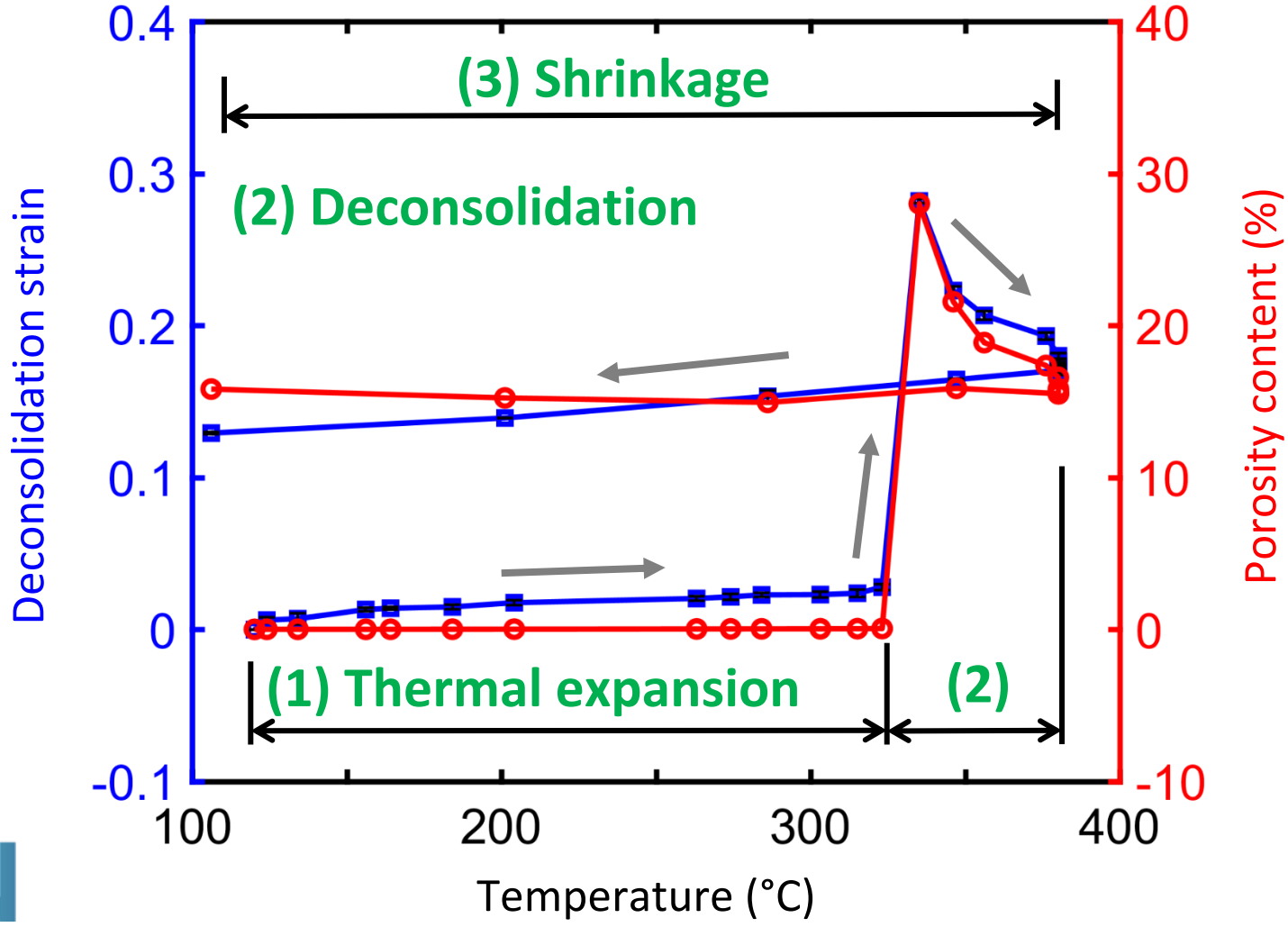
Global strain



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

Strain and porosity

- Test **2**: Dried / UD / Bi-lateral



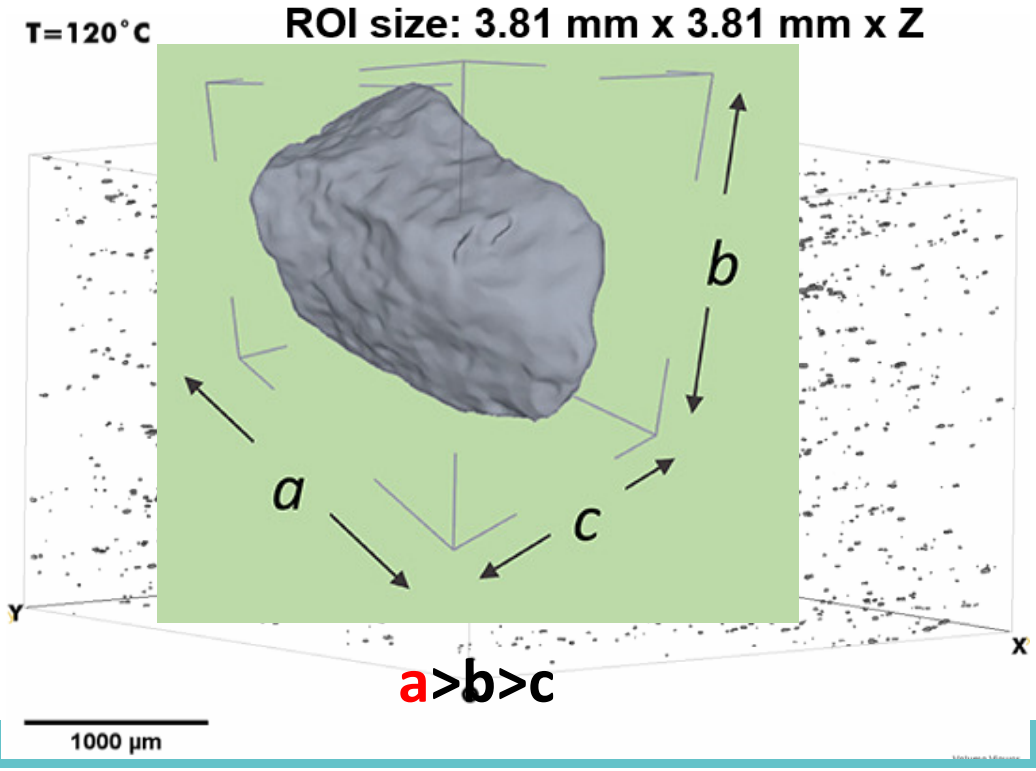
Processing

- **Pore size**
  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

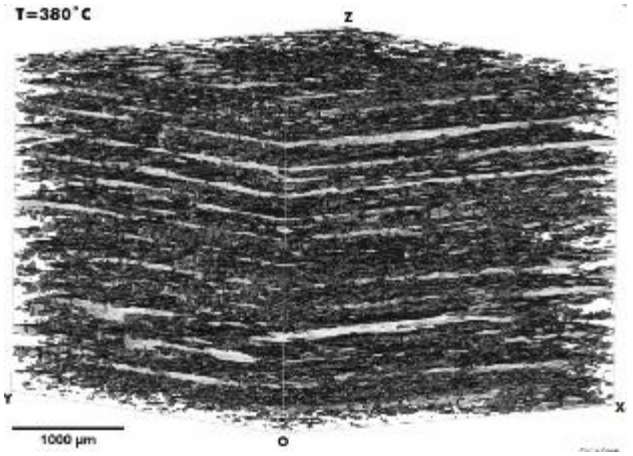
Length > 1 mm



a>b>c

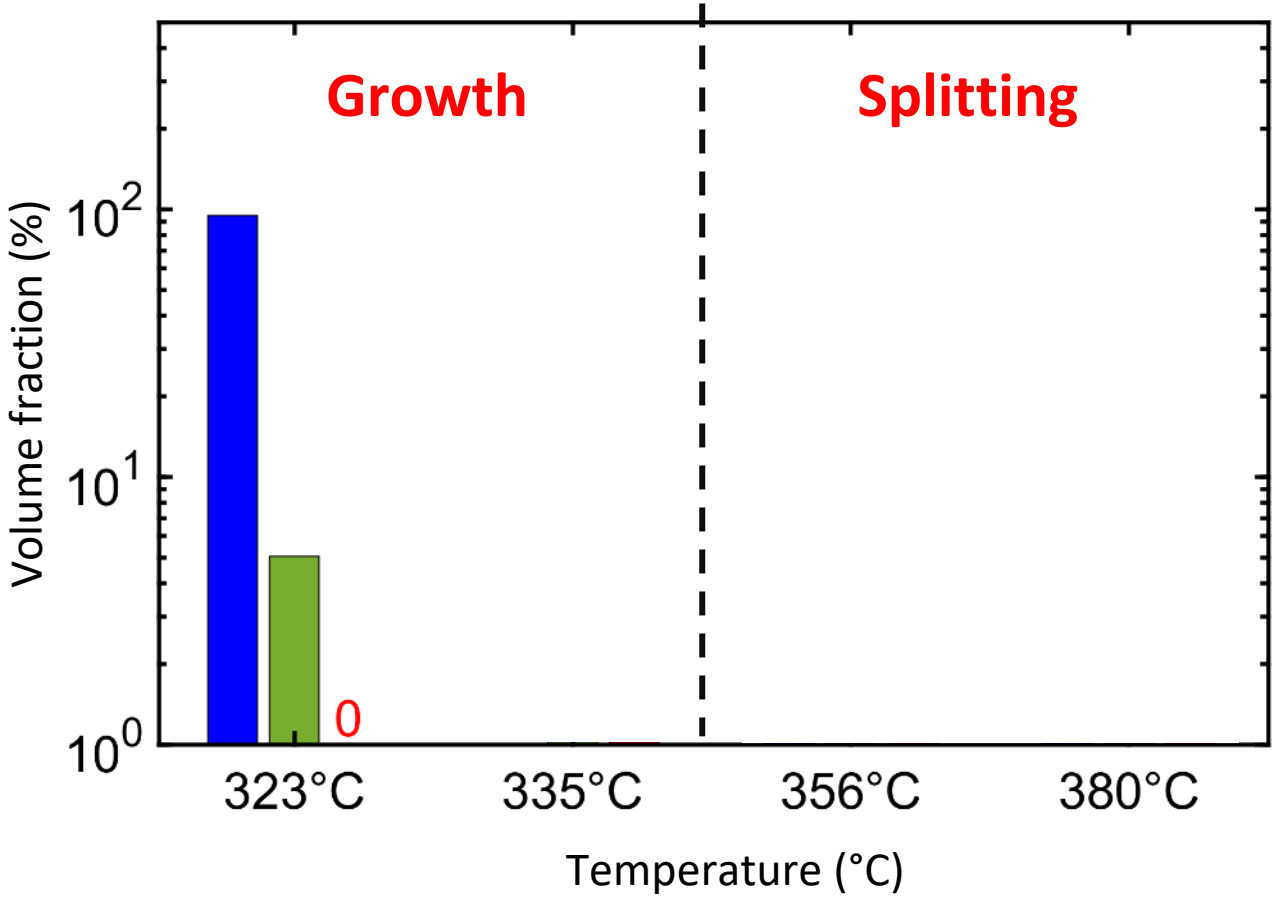
Pore growth and splitting

Test **2**: Dried / UD / Bi-lateral



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

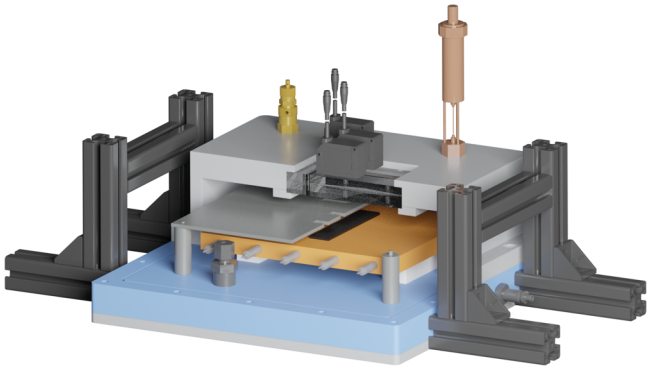
During deconsolidation



1 - Material

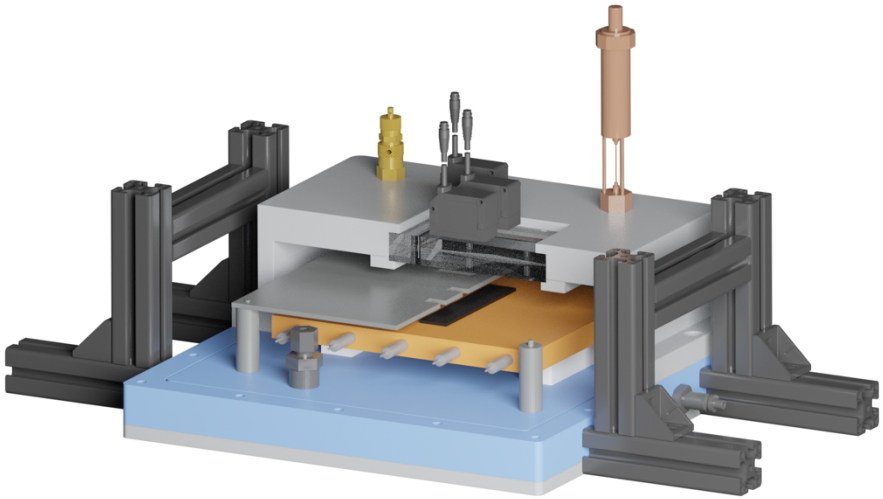
2 - Microstructural in-situ analysis

3 - Macroscopic parametric study



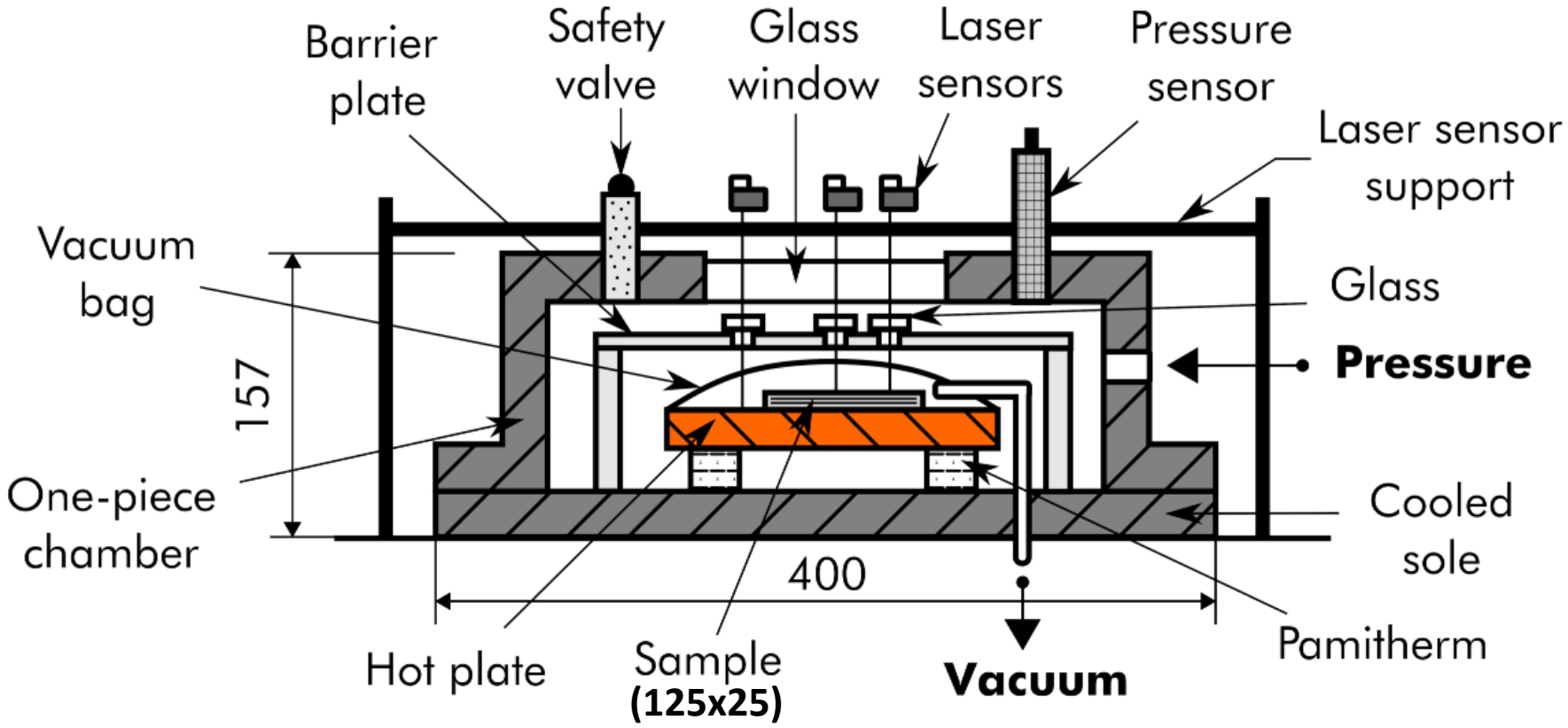
CODEC bench

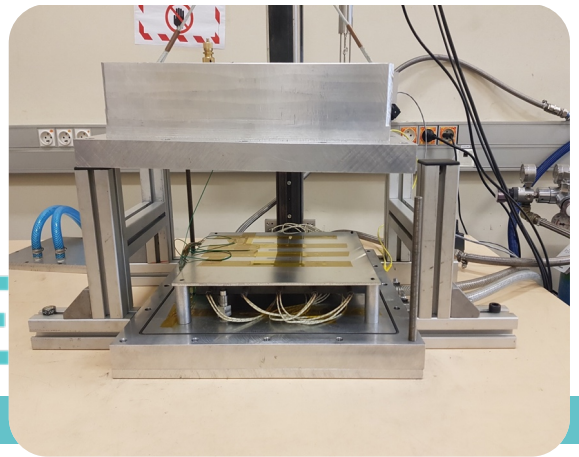
Continuous in-situ COmposite DEConsolidation



[Amedewovo et al. 23]

CODEC bench

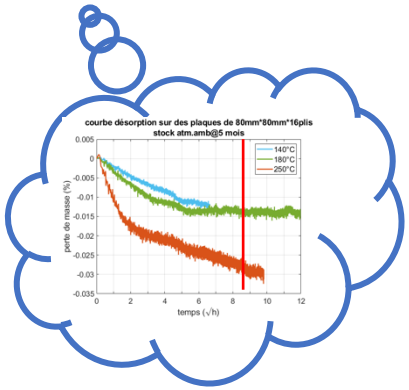


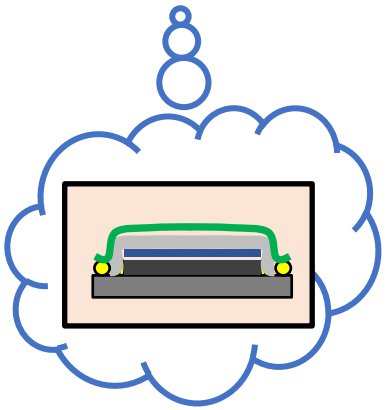


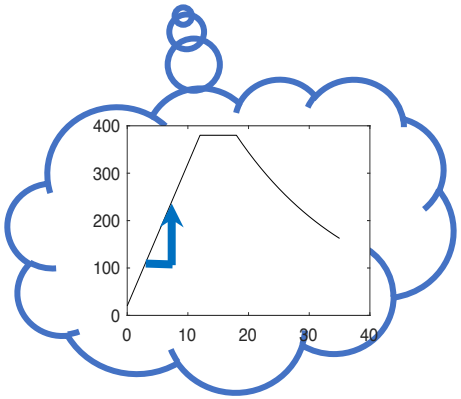
Up to 450°C
Up to 10 bars
Up to 60°C/min

Test matrix

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



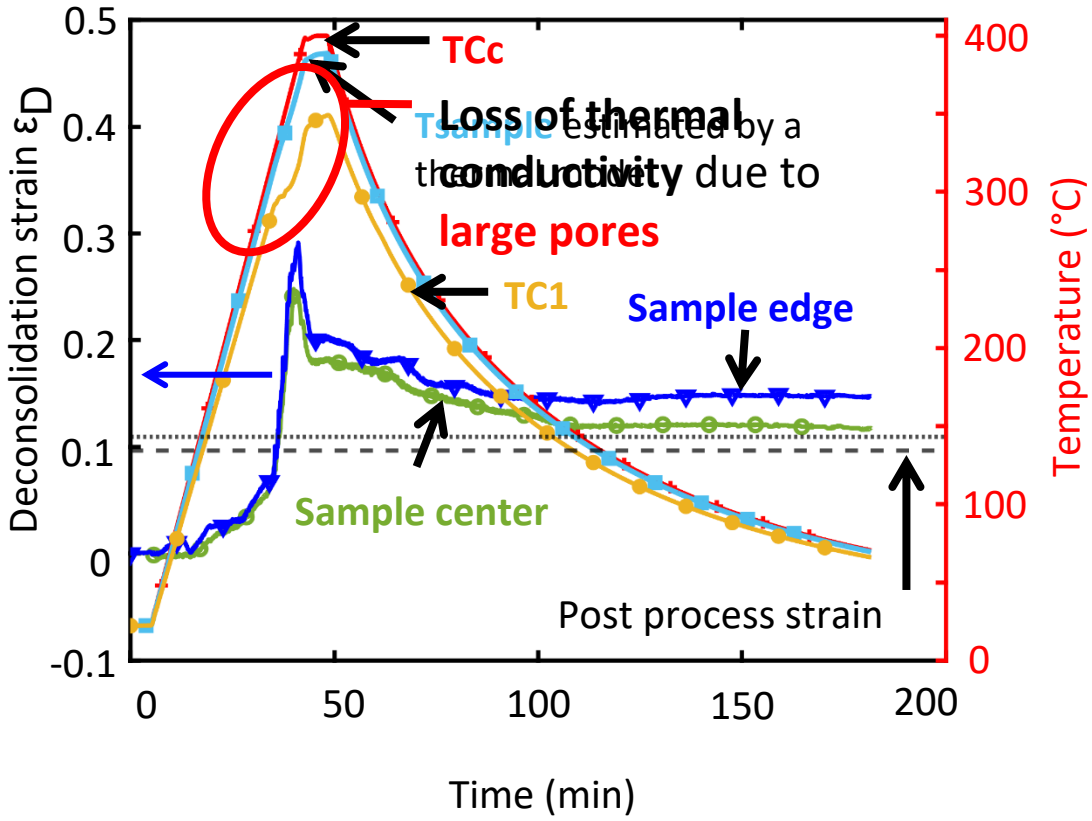




200 tests

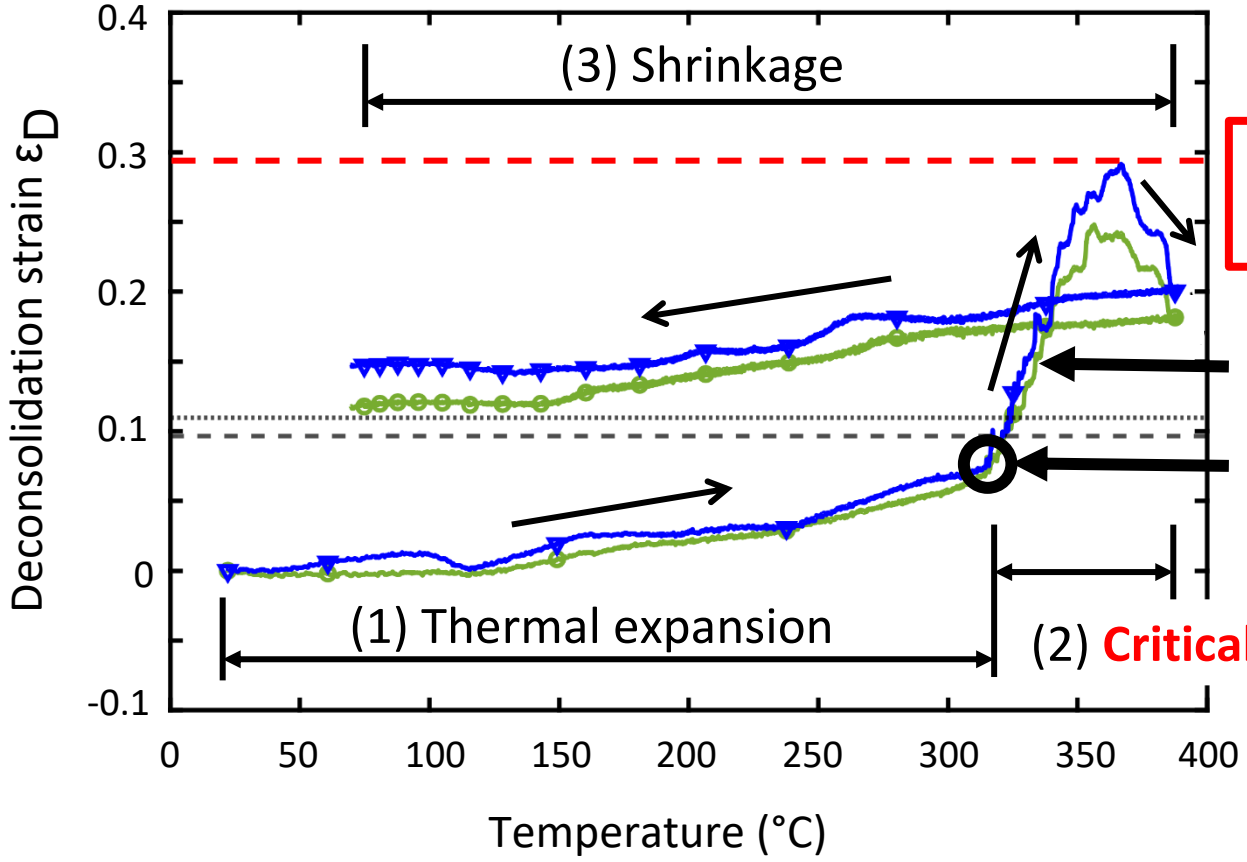
Results

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



Deconsolidation graph

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



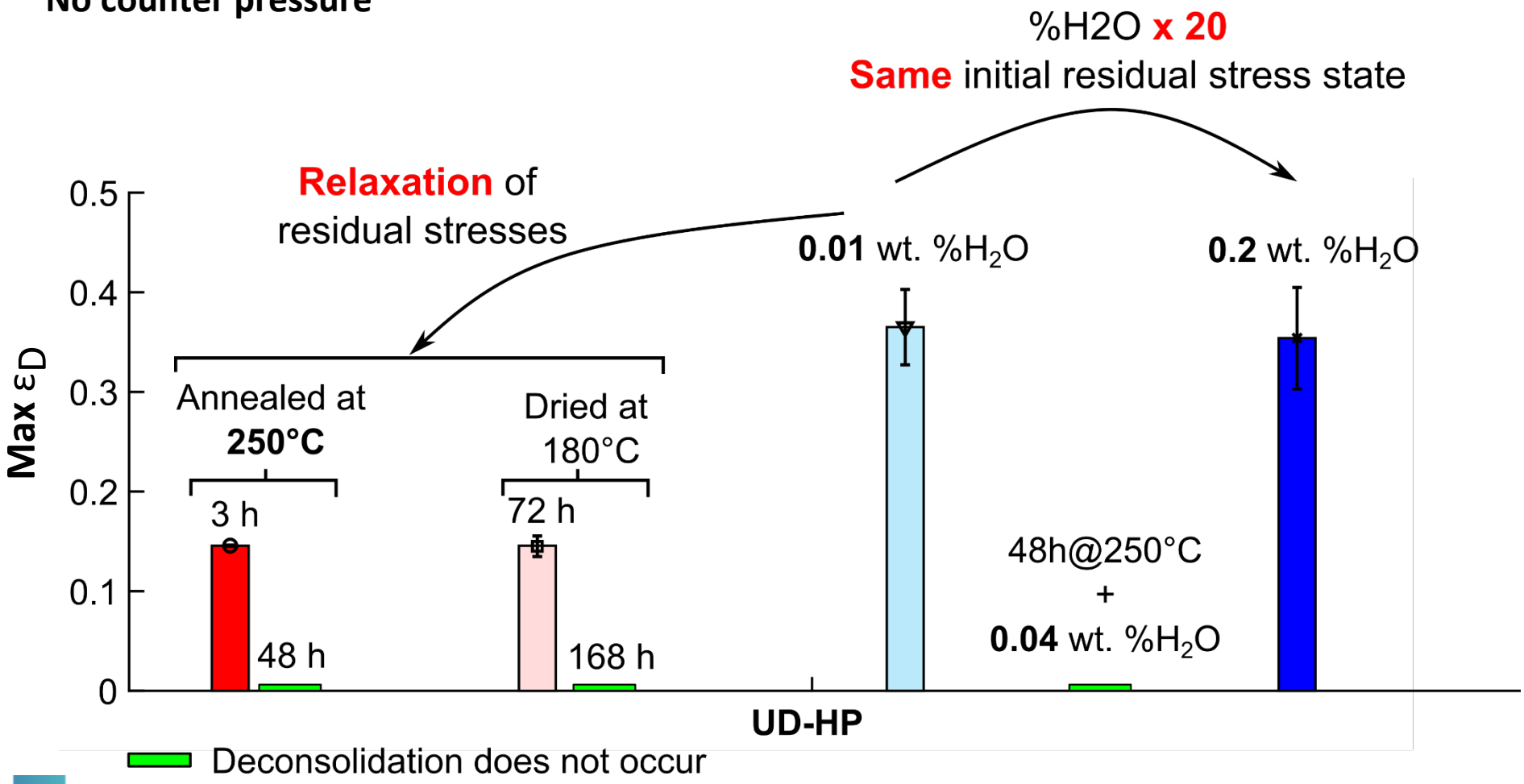
Max deconsolidation strain

DTS ($°C^{-1}$)

Deconsolidation critical temperature T_D

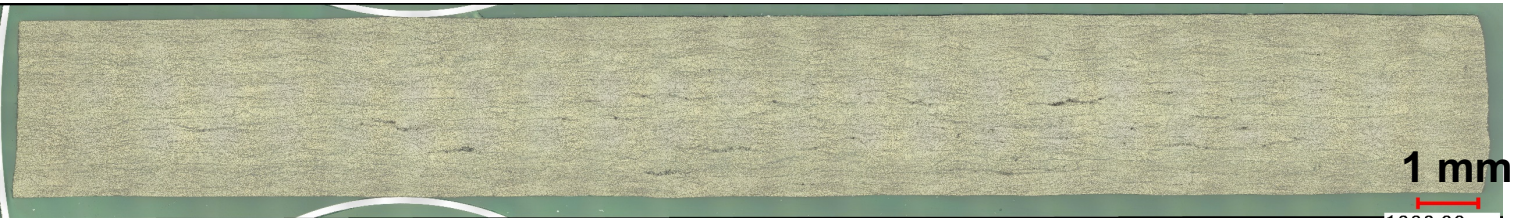
Maximum deconsolidation strain

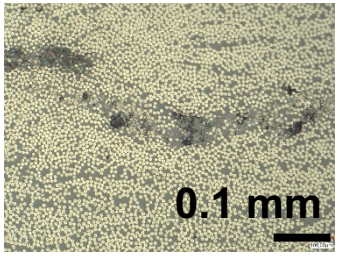
Heating rate =10°C/min
No counter pressure



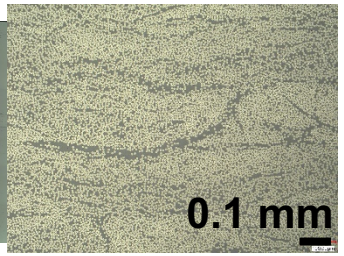
After experiments micrographs

UD- HP - Dried (DS) 1 week@180°C

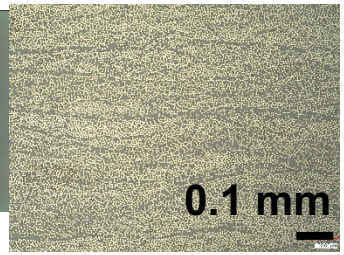




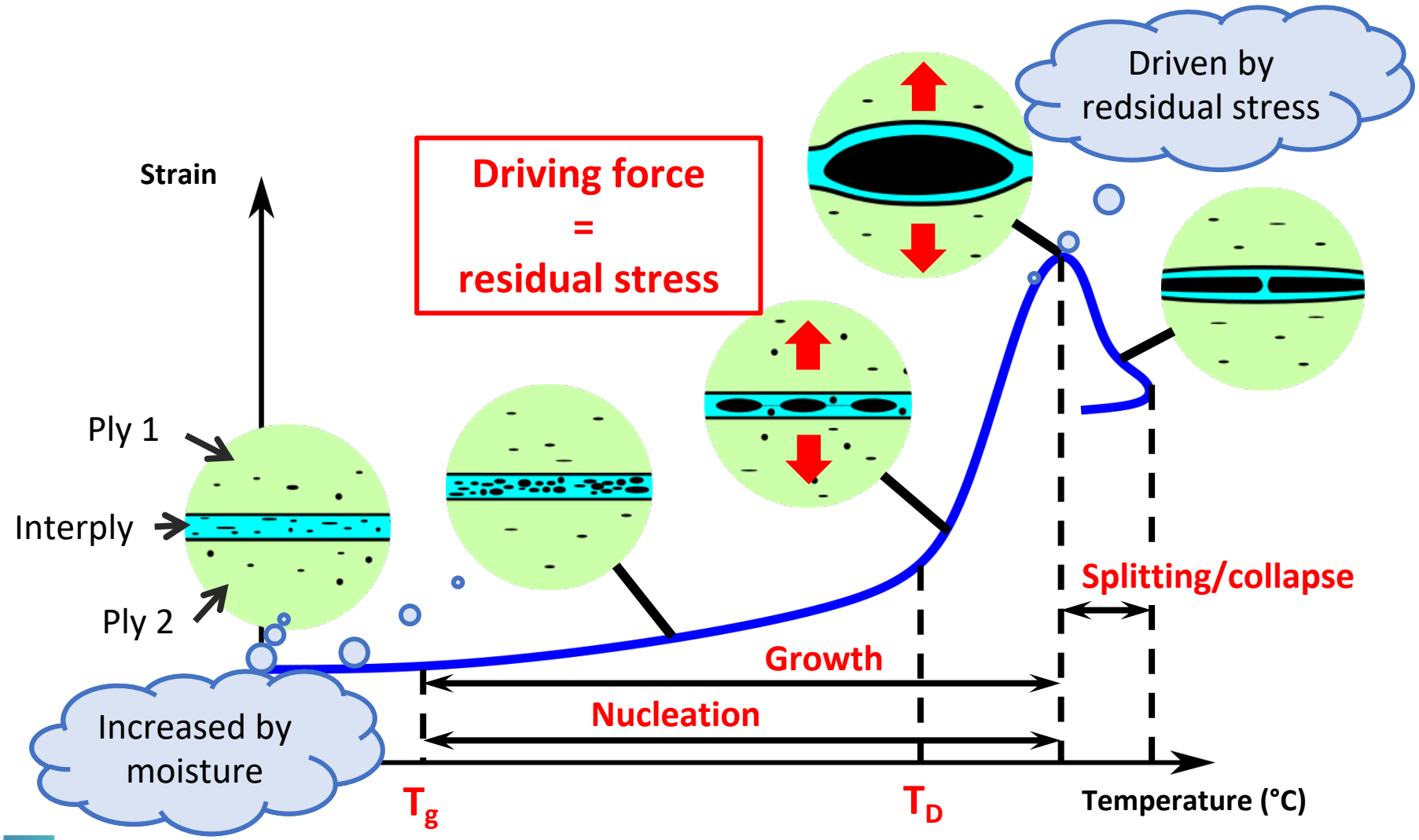
UD - HP - Annealed (AN) 48h@250°C



UD - HP - Annealed (AN) 48h@250°C +
Rehumidifying 1 week 0.04 wt. %H_2O



Conclusions



Acknowldegement

- 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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