



“ When the physical world meets, uniquely, the virtual world for a premium manufacturing, maintenance, and repair approach of the next generation aircraft composite structures ”

Smart Manufacturing in AFP: Predicting Composite Quality Through Process Data

EASN International Conference

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Content

1. Main Objectives
2. Materials
 1. 3R-resin tapes with customized Tg
3. ATL manufacturing
 1. ATL Process Window Optimization
 2. 3R Complete Characterization vs. commercial material
4. ATL manufacturing process monitoring system
 1. Data digitalization: Temperature and Pressure
5. Conclusions and next steps

Main Objectives

Revolutionize aircraft lifecycle management through **AI-powered, sustainable, and connected digital twin technologies.**

Advanced Manufacturing:

Combine novel 3R-resin with customized Tg and embedded FOS, automated processes, and AI-based optimization.

→ *35% lower manufacturing costs, 55% less scrap.*

Smart Health Monitoring:

Use digital twins, HPC simulations, and wireless sensors for predictive maintenance.

→ *30% reduction in maintenance costs.*

Digitalized Repair:

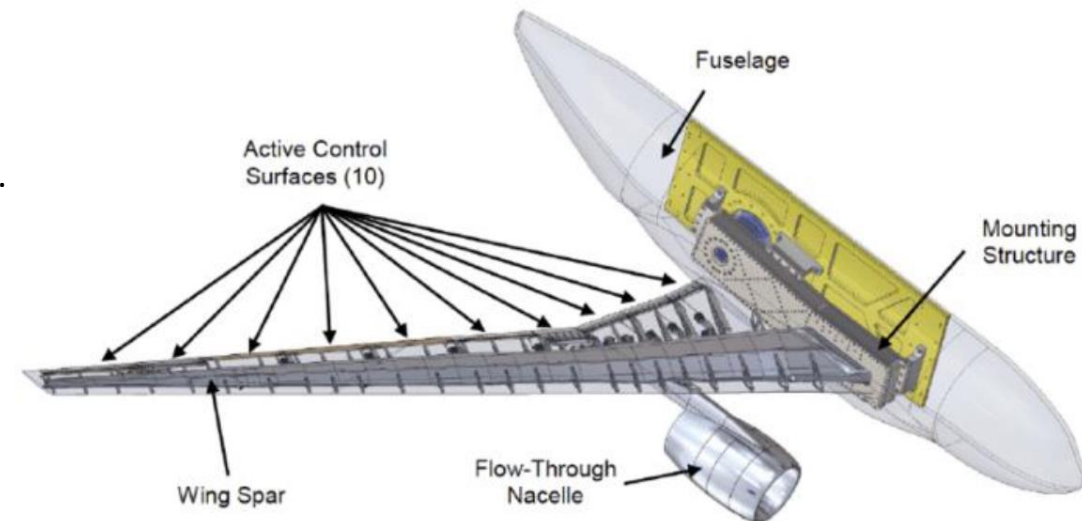
Apply AR, laser systems, and smart materials for faster, safer composite repair.

→ *30% faster repairs, 40% stronger bonds.*

Lifecycle Digital Twin Framework:

Create an interoperable platform ensuring continuous data flow and knowledge sharing across all lifecycle phases.

→ *Full digital continuity from design to end-of-life.*

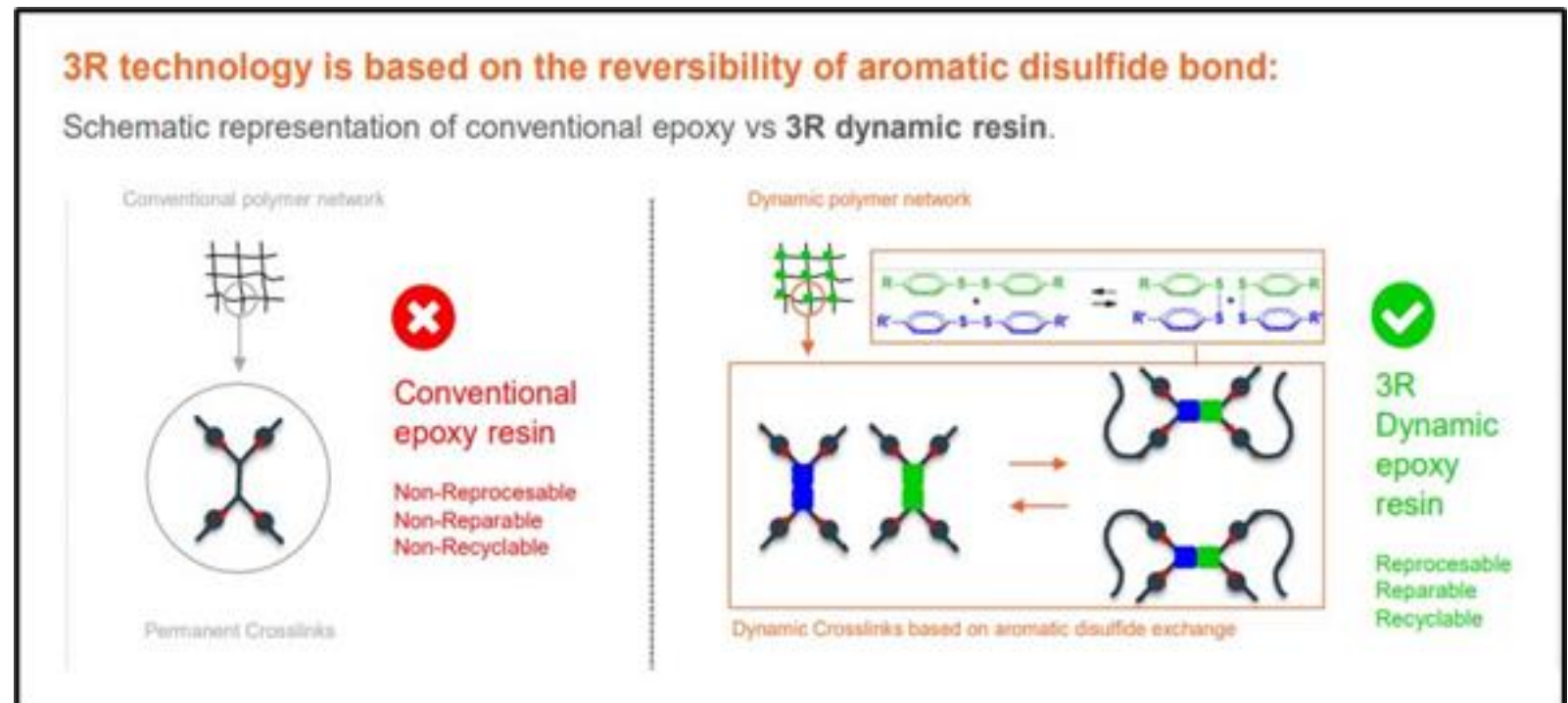


3R-resin tapes with customized Tg

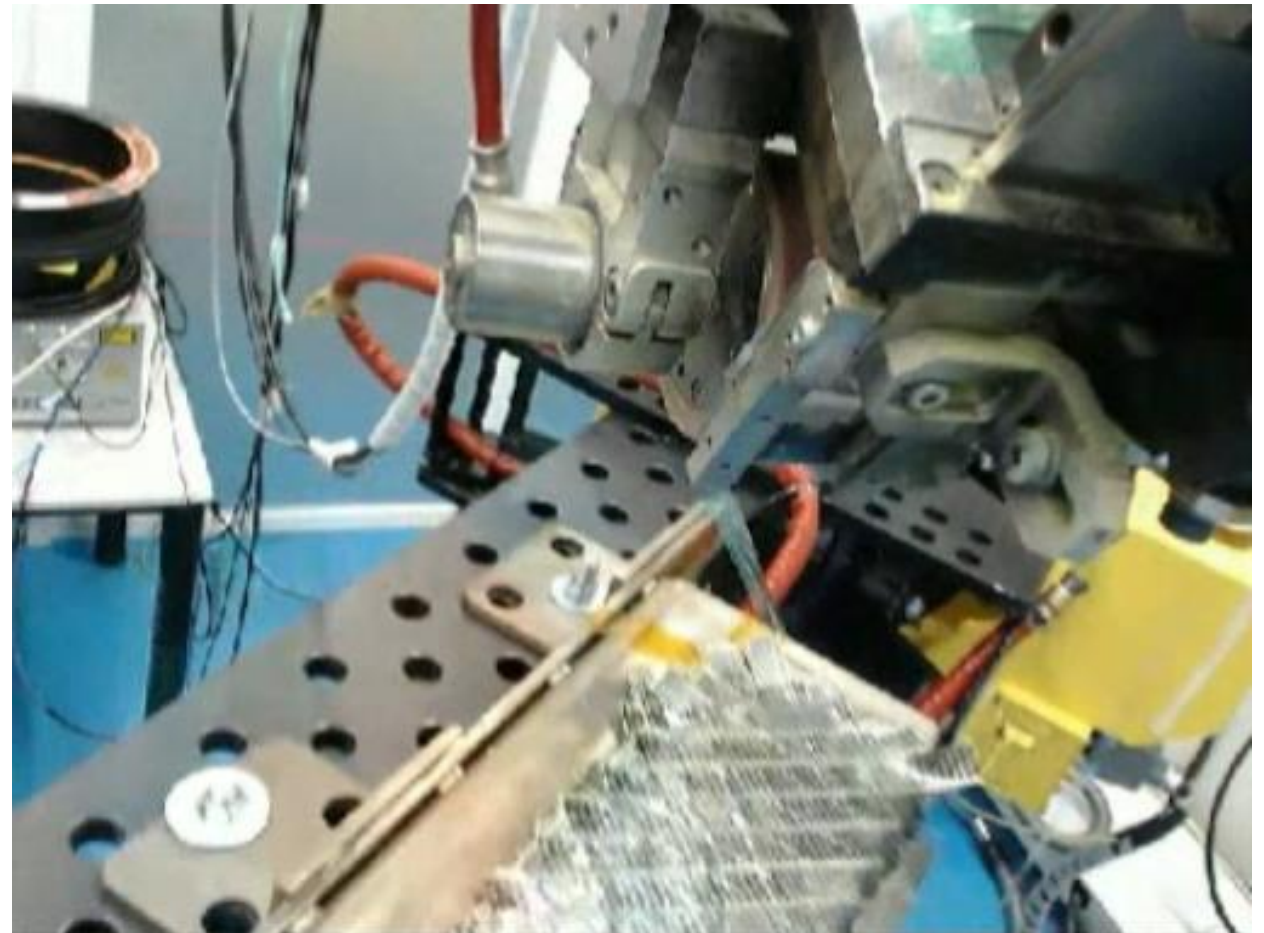
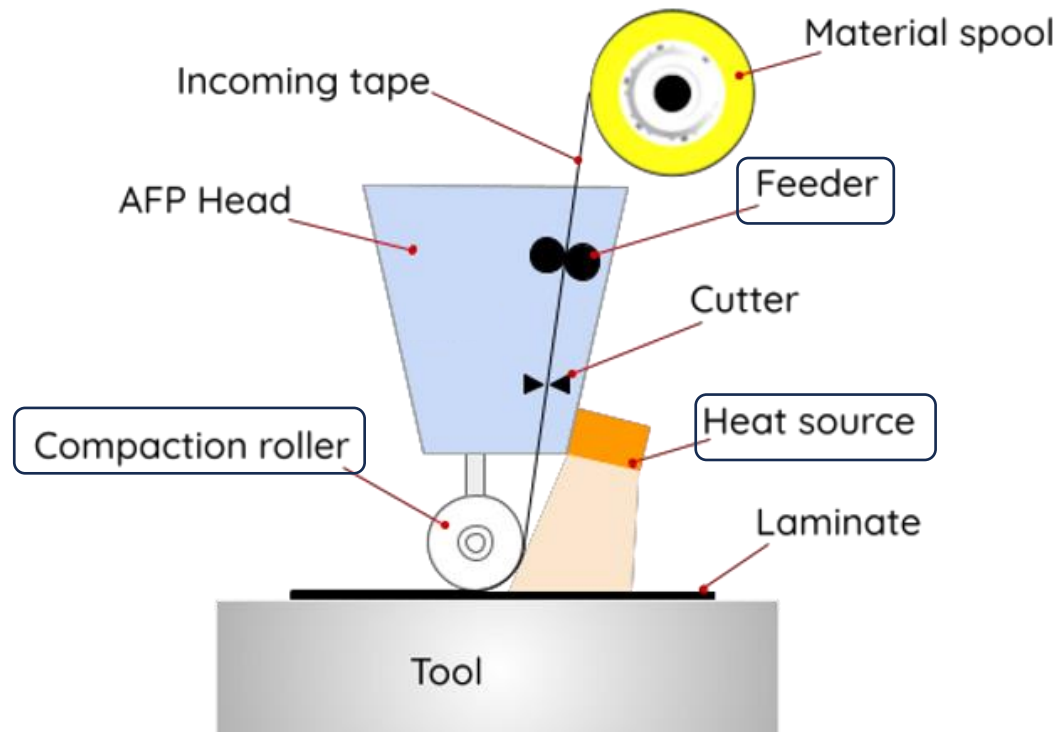
Formulation and characterization of vitrimers: formulation based on epoxy + dynamic hardener

Characterization of thermoplastic-like thermoset resins (3R Resin):

- ✓ Dynamic covalent network
- ✓ Reprocessable
- ✓ Reparable
- ✓ Recyclable
- ✓ Controllable viscous flow
- ✓ Covalent bond-exchange reactions
- ✓ Enhanced sustainability
- ✓ Reinforcement compatibility
- ✓ Post-curing processability



ATL manufacturing



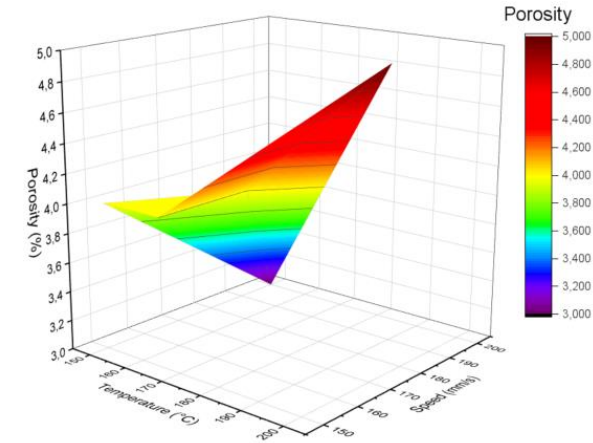
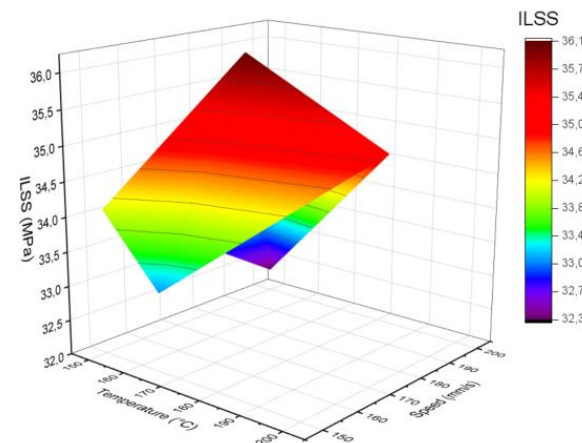
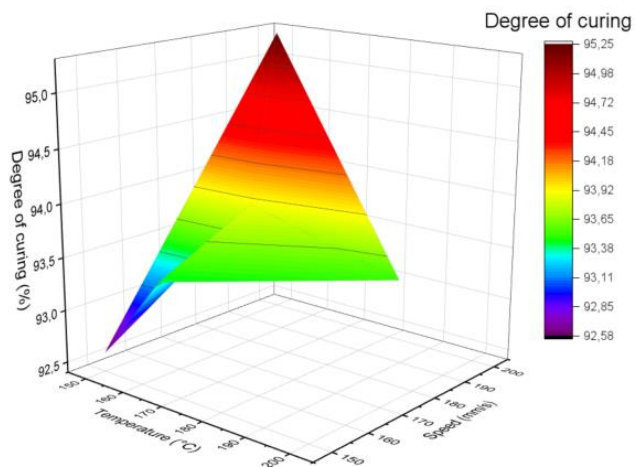
ATL Process Window Optimization

ATL parameters	
Temperature (°C)	Speed (mm/s)
150	150
150	200
165	150
165	175
200	175

Post-curing cycle:
1h at 130 °C + 30 min at 180 °C
(Ramp 1°C/min)



Process Outputs after over curing		
Degree of curing (%)	ILSS (MPa)	Porosity (%)
92,58	32,33 ± 1,5	4
95,25	34,1 ± 2,20	3
93,42	33,13 ± 2,44	4
93,8	36,17 ± 3,16	4
93,5	35,12 ± 0,81	5



3R Complete Characterization vs. commercial material

Process inputs		
	3R Resin	HEXPly M21 Resin
Manufacturing Process	ATL + Oven	Autoclave
Temperature (°C)	ATL: 150	180
	Oven: 180	
Pressure (bar)	ATL: 14 ± 0,5	7
	Oven: 1	
Speed	ATL: 200 mm/s	≈ 345 minutes
	Oven ≈ 350 min	



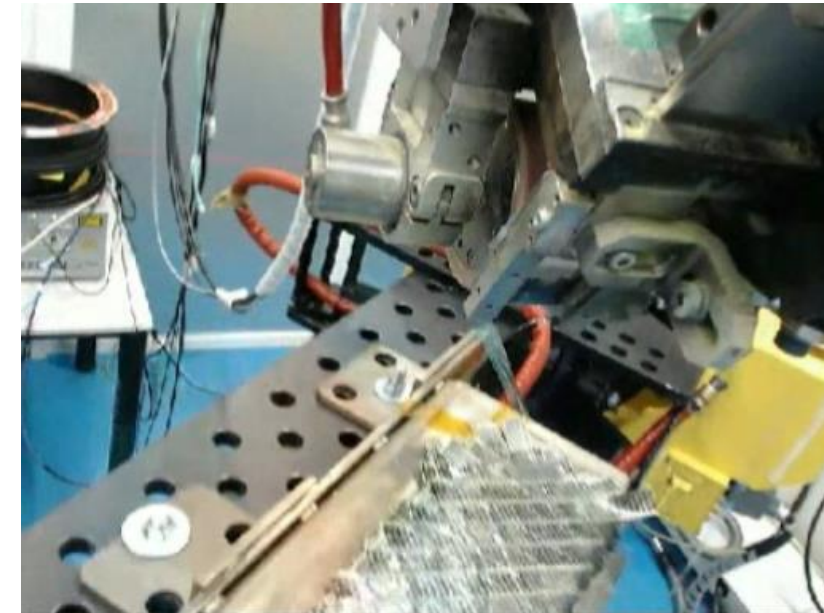
The 3R Resin offers:

- ✓ Lower curing temperature and higher energy efficiency.
- ✓ Out-of-Autoclave (OoA) processability, suitable for sustainable manufacturing.
- ✓ Balanced mechanical properties.
- ✓ Lower glass transition temperature (T_g), limiting its use in high-temperature structural applications.
- ✓ Higher fiber content and low porosity, indicating good impregnation quality.

Process outputs		
	3R Resin	HEXPly M21 Resin
Tensile strength at 0° (MPa)	2043 ± 77,9	3050 ± 442
Tensile Modulus at 0° (GPa)	102 ± 10,3	178 ± 25,8
Poisson coefficient at 0°	0,28 ± 0,03	0,33
Tensile strength at 90° (MPa)	21,4 ± 3,6	
Tensile Modulus at 90° (GPa)	8,47 ± 0,48	9 ± 0,1
Poisson coefficient at 90°	0,02 ± 0	
Max. Shear Strength (Mpa)	63,7 ± 2,23	94 ± 13,6
Chord Shear Modulus, G12 (GPa)	3,82 ± 0,05	5,2 ± 0,75
Degree of cure (%)	94,11 ± 1,52	
T _g (°C)	159,15 ± 5,18	195 ± 383
Carbon fibre content (%)	62,17 ± 1,48	59,2
Porosity (%)	1,5 ± 1,5%	

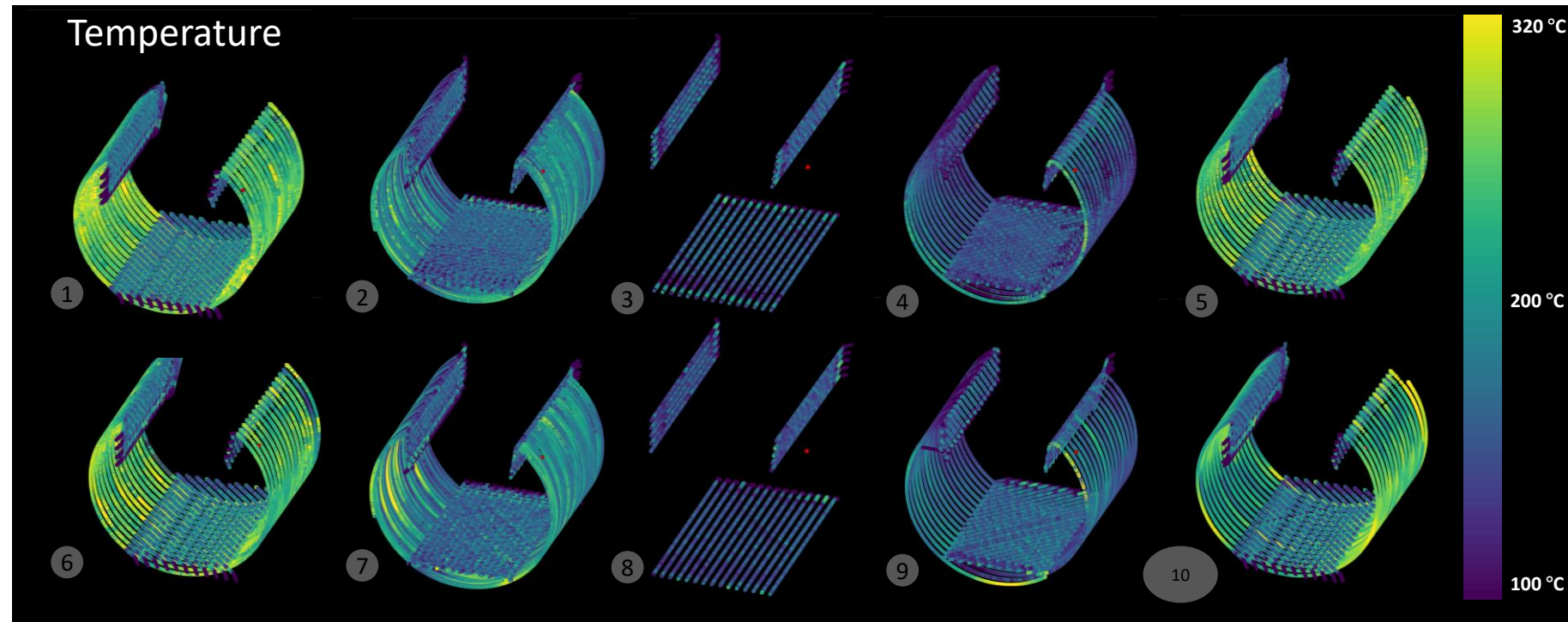
ATL manufacturing process monitoring system

- ✓ Manufacturing process monitoring system with inline data transfer to the digital twin



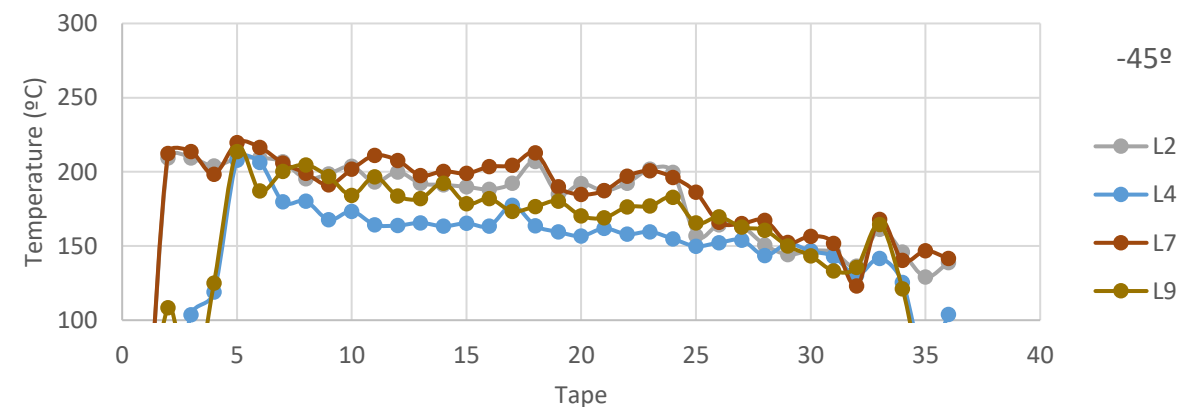
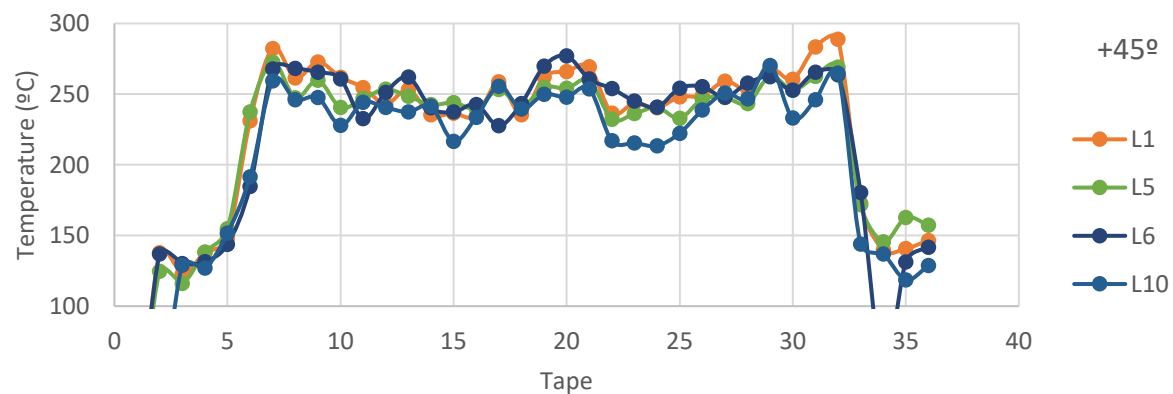
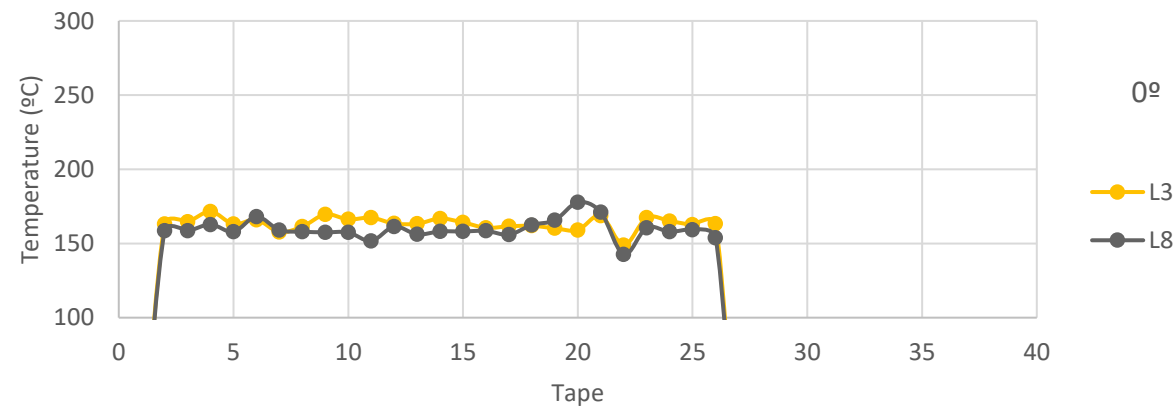
Data digitalization - Temperature

DEMO stacking (21 layers): [45/-45/0/-45/45/90/-45/45/45/-45/90/-45/45/45/-45/90/45/-45/0/-45/45]



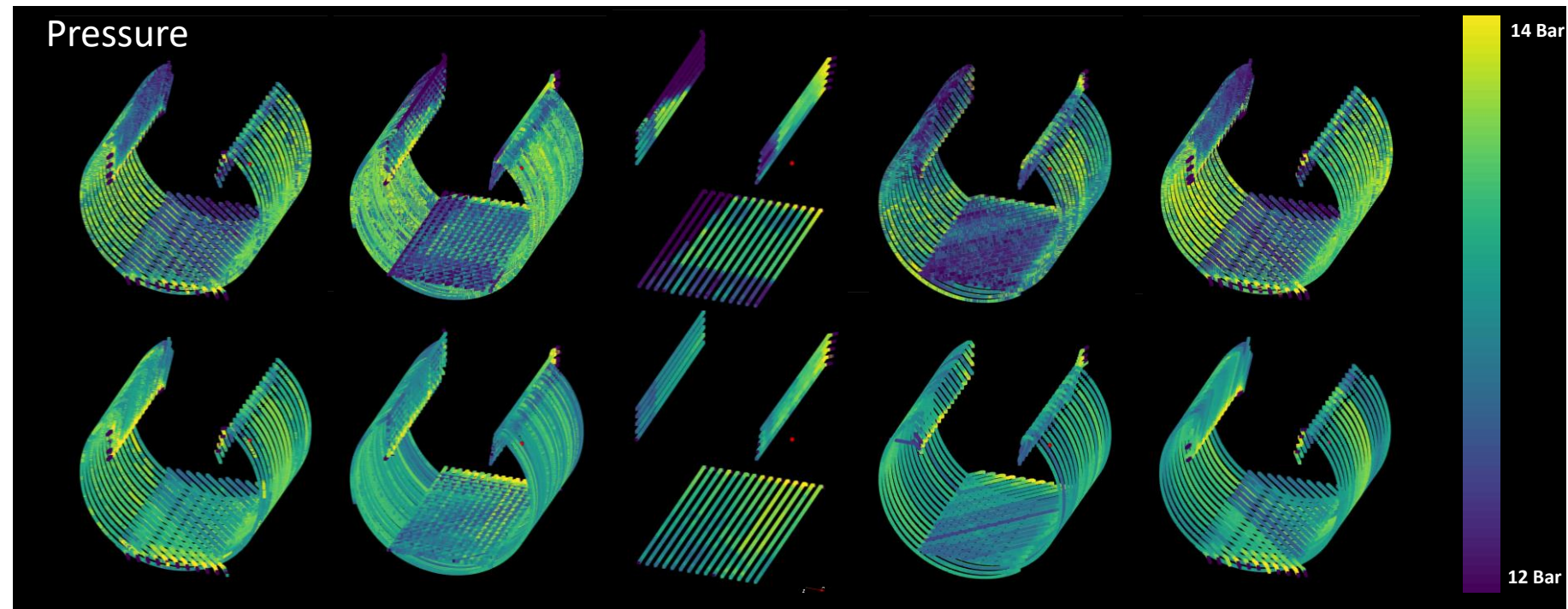
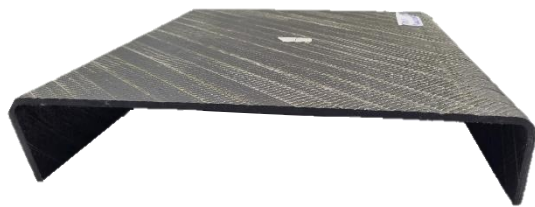
Data digitalization - Temperature

Average temperature distribution per tape



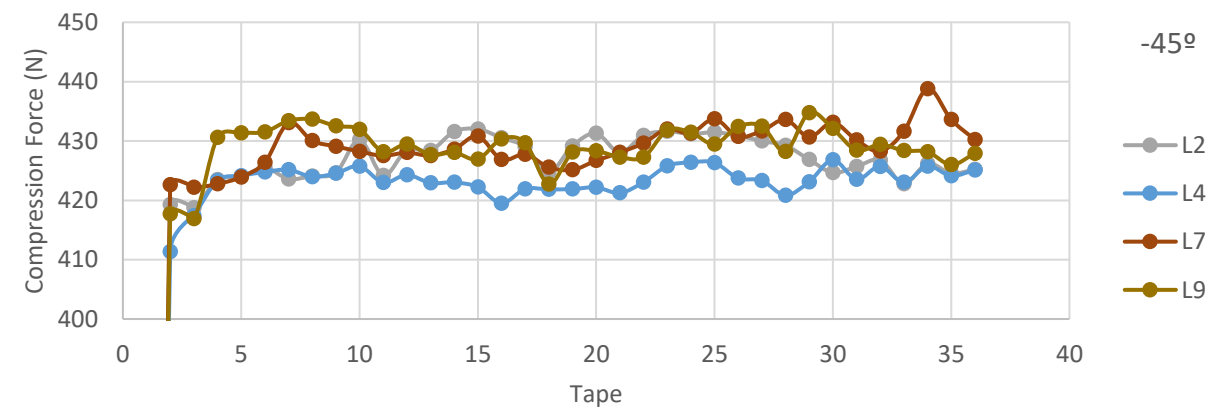
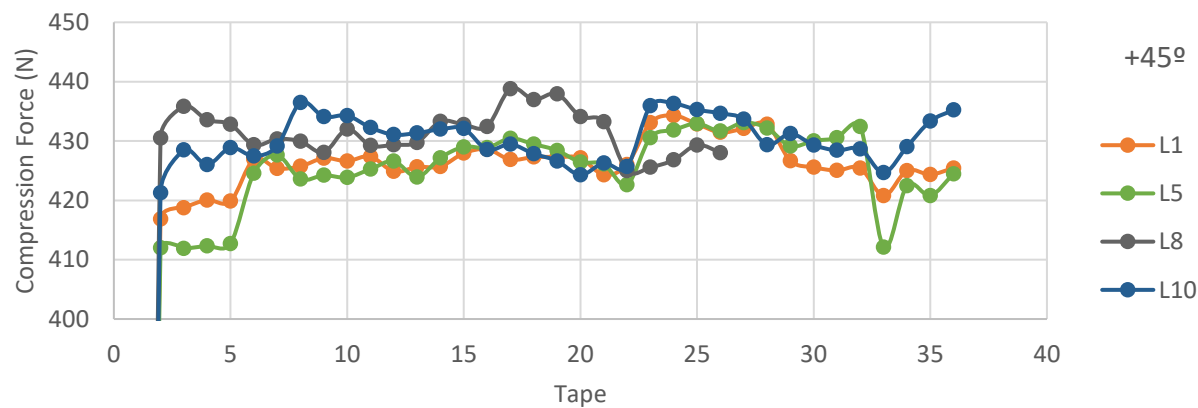
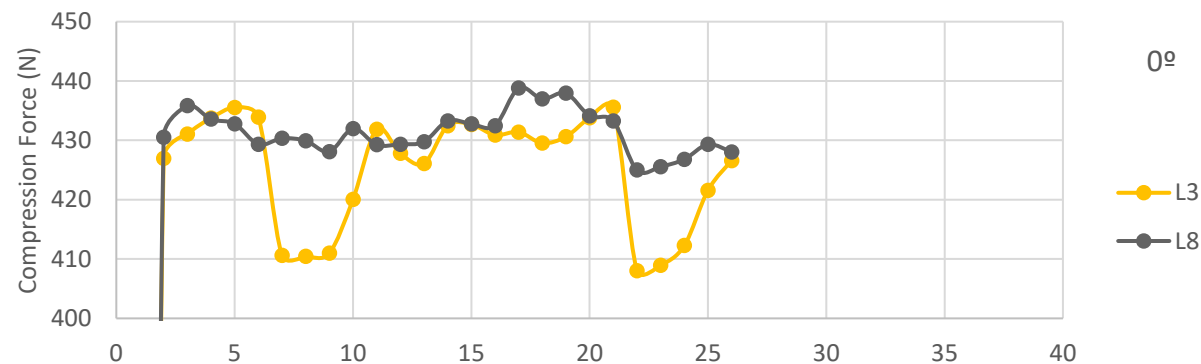
Data digitalization - Pressure

DEMO stacking (21 layers): [45/-45/0/-45/45/90/-45/45/45/-45/90/-45/45/45/-45/90/45/-45/0/-45/45]



Data digitalization – Compression force

Average compression force per tape



Conclusions and next steps

Conclusions

- Materials and process
 - Stable ATL process window with good curing degree and low porosity.
 - 3R-resin proved to be a technically viable and sustainable alternative
- Monitoring & Digitalization
 - Visualization tool useful for process control
 - Advanced analysis
 - Temperature and Pressure variations



Next steps

- Validation through 5 demonstrators
- Correlation between temperature and pressure digital twins, mechanical properties, and failure modes

THANK YOU!



Acknowledgement

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