Optimizing the vacuum assisted resin infusion process for carbon fiber laminates with Akelite resin

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MATRICES FOR SUSTAINABLE COMPOSITES

Bio-based matrices

- Commercial grades with up to 30 % bio-based
- Similar properties
- Limited recyclability

Vitrimers

- Dynamic covalent bonds
- Reprocessability
- Recyclable

Thermoplastic

- Reprocessability
- Recyclable
- High viscosity ➔ reactive systems

AKELITE RESIN

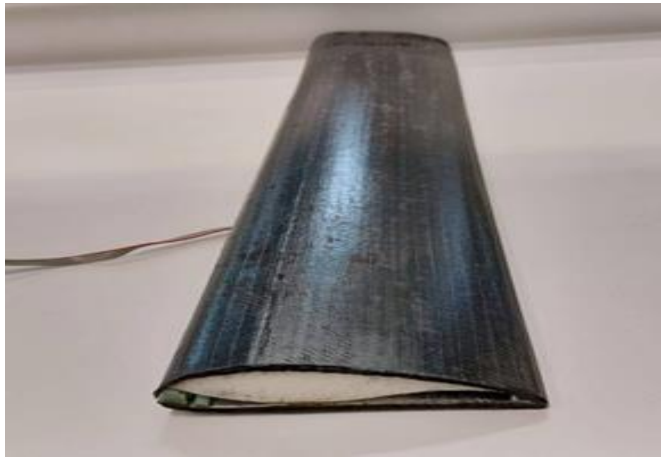
Akelite

- Patented by CSIC, acrylic based resin
- 100% Circular – recover both fibers and matrix
- Conventional fabrication processes: RTM, VARI…
- Controlled and mild processing parameters
- Easy impregnation of commercial fibers
- Production of semi-elaborates

Laminate	% FC weight	Thickness (mm)	Flexural				ILSS (MPa)
			Longitudinal		Transversal		
			σ_{max} (MPa)	E (GPa)	σ_{max} (MPa)	E (GPa)	
Akelite	65,8	1,4 ± 0,1	1.045 ± 59	59 ± 4	79 ± 5	5,1 ± 0,5	58 ± 1
Epoxy (Resoltech)	69,6	1,4 ± 0,1	957 ± 67	59 ± 7	90 ± 5	6,6 ± 0,8	50 ± 3

AKELITE RESIN

Prototypes

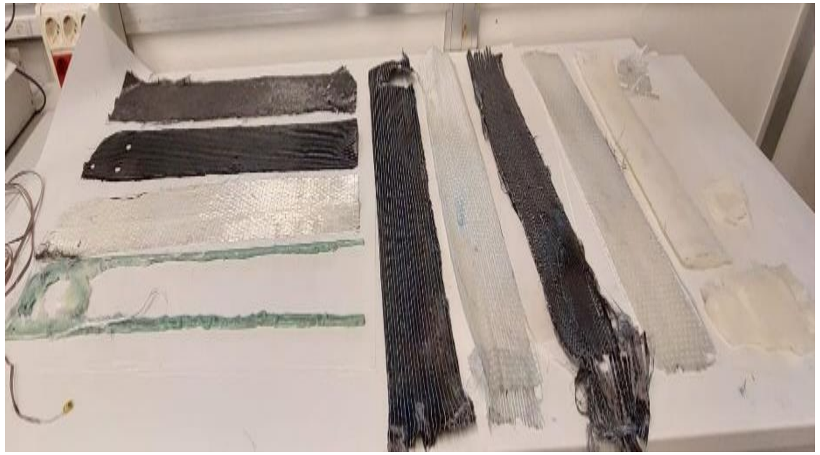


Thermoforming

T= 150ºC +
light pressure

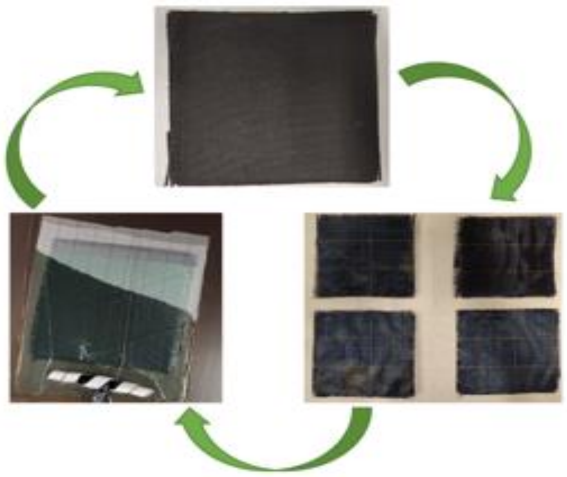
RECYCLING

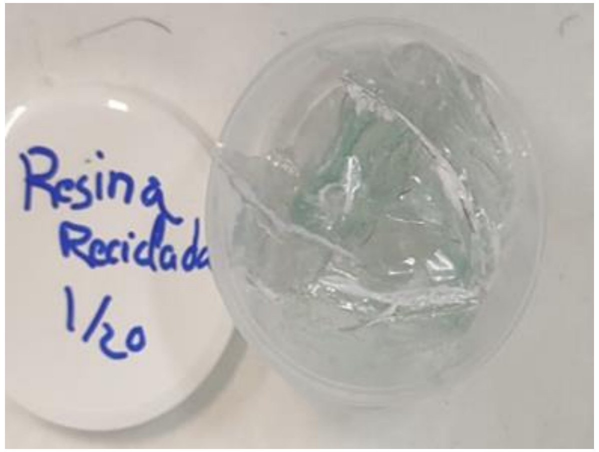
Method	Immerse the laminate in acetone.
Time	18 hours.
Result	The carbon fiber panels could be separated, managing to remove more than 95% of the resin they had.
Acetone and resin recovery	Evaporation - condensation process: rotary evaporator



RESULTS RECYCLING

Test	Virgin		Recycling	
Flexural	Longitudinal	Transversal	Longitudinal	Transversal
σ (MPa)	488 ± 92	293± 99	469 ± 59	346 ± 75
E (GPa)	23 ± 7	15 ± 6	24 ± 3	16 ± 4
ILSS (MPa)	32 ± 2		26 ± 6	





VARI OPTIMIZATION

Stage	Temperature, °C	Time, h	PB, %	Vacuum, %
1	70	2	1	100
	70	2	2	100
	70	2	3	100
2	70	2	3	80
3	60	2	3	100
	70 + 80	2 + 1	3	100

- Economical
- High fiber content
- Large dimensions

VARI OPTIMIZATION

Stage	Laminate	Flexural				ILSS (MPa)
		Longitudinal		Transversal		
		σ_{max} (MPa)	E (GPa)	σ_{max} (MPa)	E (GPa)	
1	1-2	529.2 ± 59.3	44.6 ± 17.2	60.1 ± 4.0	1.4 ± 0.6	45.2 ± 2.7
	3-4	879.2 ± 35.0	54.9 ± 5.0	85.5 ± 8.0	2.7 ± 0.4	58.5 ± 2.4
	5-6	927.8 ± 72.0	57.0 ± 3.2	89.7 ± 7.4	2.4 ± 0.4	57.8 ± 4.3
2	7-8	856.1 ± 27.2	51.6 ± 5.6	69.7 ± 4.6	3.0 ± 0.4	53.0 ± 5.7
3	9-10	732.4 ± 62.5	54.0 ± 5.3	78.0 ± 2.5	2.0 ± 0.7	57.5 ± 3.3
	11-12	983.9 ± 22.0	52.7 ± 5.5	81.2 ± 6.0	2.9 ± 0.4	59.2 ± 1.9

Laminates

- UD carbon fiber 12K, 340 g/m^2 weight.
- 20 x 11 cm laminates and 4 plyes (45 µm thickness).
- 2 laminates per condition.

Characterization

- 3P bending in longitudinal and transverse - UNE-EN ISO 178:2020.
- Interlaminar shear strength (ILSS) - UNE-EN ISO 14130:2003.

CONCLUSIONS

- The optimal conditions for manufacturing carbon fiber laminates with Akelite resin were 70ºC for two hours, 100% vacuum and with 3% initiator.
- Recycling for laminates with Akelite resin is simple and fibre and resin can be recovered in addition to the solvent used.
- The property values obtained were very good and capable of competing with laminates made with thermoset matrices.
- Replace the carbon fiber reinforcement with natural fibers such as line or basalt.

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