domminio

Digital method for improved manufacturing of next-generation multifunctional airframe parts

INVESTIGATION OF THE INFLUENCES OF AFP PROCESS PARAMETERS ON THE CRYSTALLINITY AND MECHANICAL PROPERTIES OF LM-PAEK COMPOSITES

Lausanne, 27th June 2022

aimen TECHNOLOGY CENTRE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007022.

AIMEN TECHNOLOGY CENTER

1967

- **AIMEN**, was established with the aims of promoting **R&D** and high-added value **technology services** to the industry.
- **Industry supported, private centre**

2022

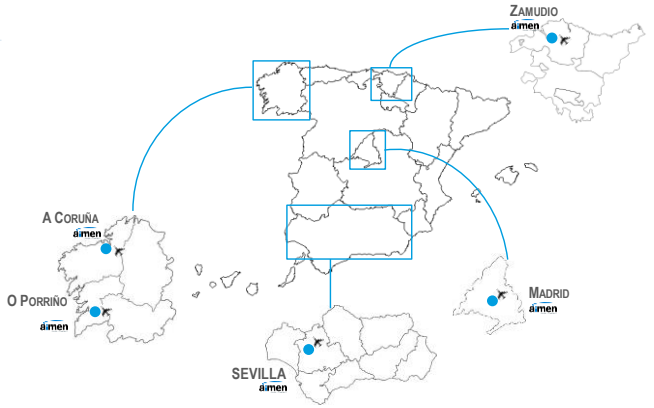
- Main technological capabilities in:
  - Materials research
  - Advanced Manufacturing
  - LASER Processing

Testing & Analysis

Industrial Services

R&D&i

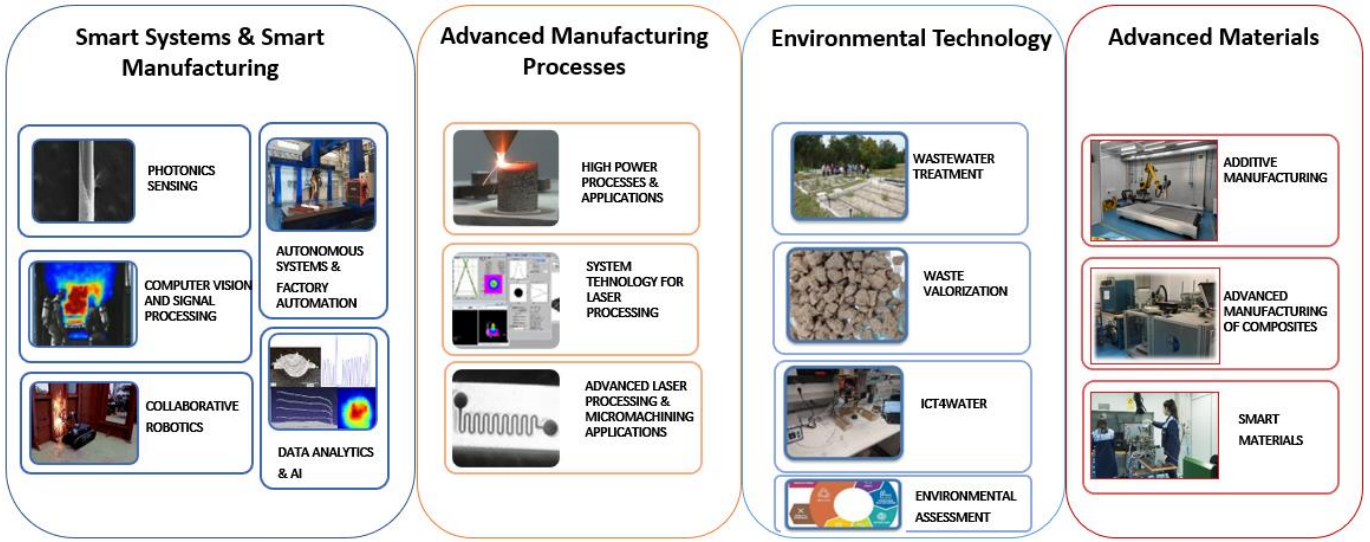
- Multisectoral Centre
- International activities in 20 countries
- Over 750 active customers
- More than **50 R&D projects per year**
- Headcount: **260** ***(50% in R&D&i)***
- **18 M€** average annual income
- Over **30 M€** in assets



Location:

- HQ and Laser Processing Centre (O Porriño, Galicia)
- Offices in A Coruña, Sevilla, Basque Country and Madrid

R&D Areas



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Introduction

AFP (Automated Fibre Placement) have been used for decades in aerospace industry, for manufacturing large structures, usually with thermoset composites. In recent years, the processing of thermoplastic composites with AFP is being studied.

Thermoplastic composites offer advantages such as unlimited shelf life at room temperature, reciclability or reprocessability.

This work studies the importance of **crystallinity** in the bonding of thermoplastic tapes, characterizing **interlaminar fracture toughness** as a combined effect of matrix ductility (inversely proportional to crystallinity) and fibre-matrix interface bond (proportional to crystallinity).

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AFP tape

Material: semi-crystalline low melt PAEK thermoplastic matrix and a T800G carbon fibre reinforcement:

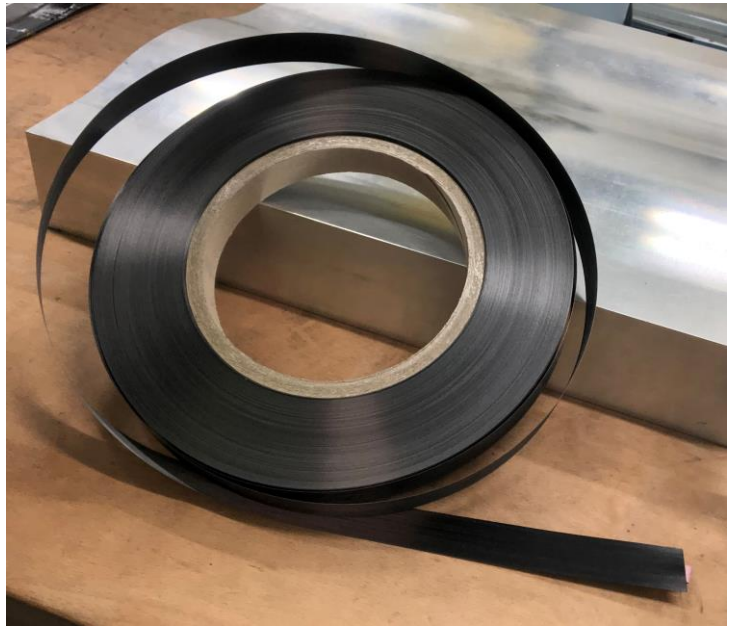
Toray Cetex® TC1225 LMPAEK / T800G UD tape

Material properties of matrix.

Material	Tm (°C)	Tg (°C)	Recommended processing temperature by supplier (°C)
LM-PAEK TC1225	305	147	340-385

Composite tape format

Material designation	Fiber Areal Weight, FAW (g/m^2)	Resin content (%)	Ply Thickness (mm)	Width (mm)
TC1225 LMPAEK / T800G UD	145	36	0.145	25.4



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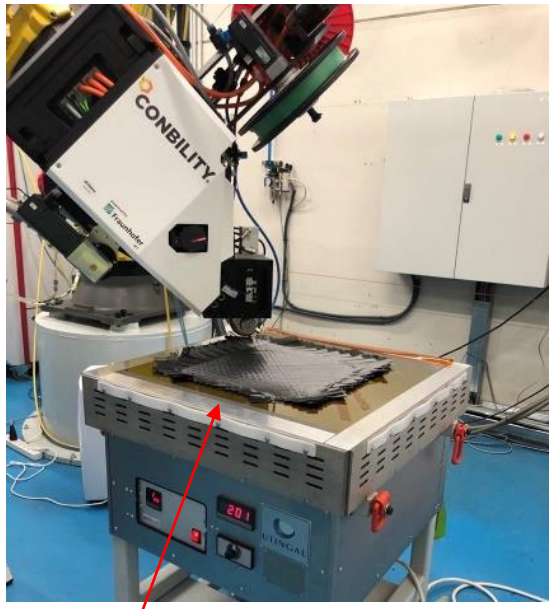
Equipment

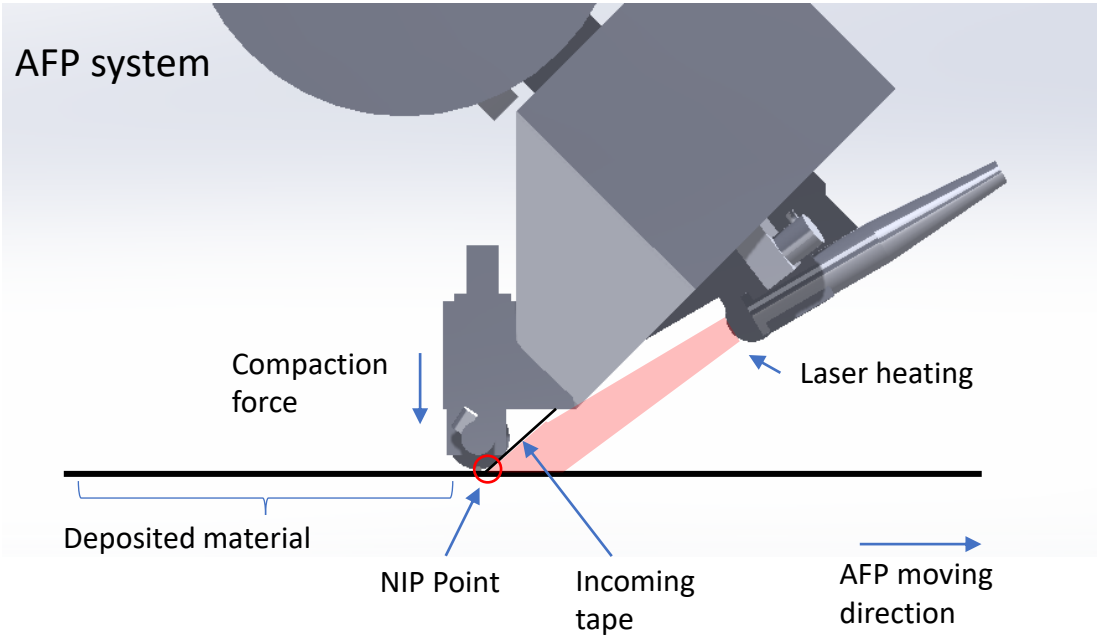
AFP (Automated Fibre Placement) head system: PrePro3D model from Conbility manufacturer.

The AFP system is mounted in a FANUC R-2000iC/165F Robotic Arm.

Heated layup tool. Aluminium alloy plate heated with resistances.

Laserline diode laser source (model LDF6000-40) of 6300W and operating wavelengths ranging from 940 to 1060 nm.





AFP parameters

AFP Parameter	Value
Layup speed [m/s]	0.25
Pressure [bar]	5.5

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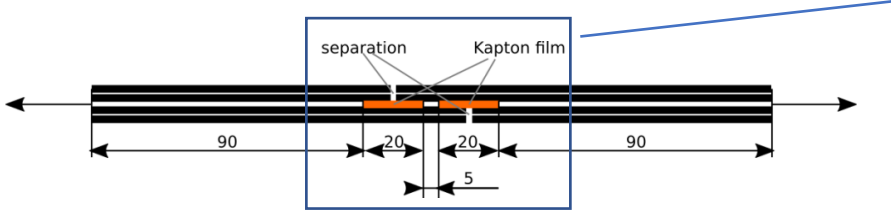
Coupon manufacturing

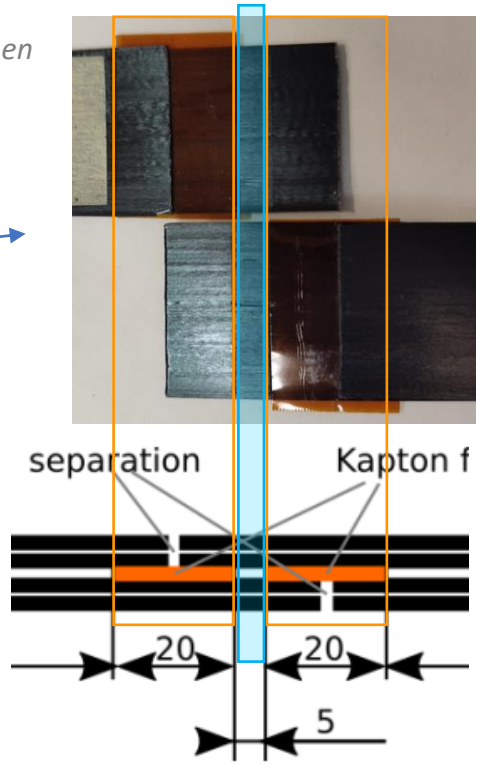
SLSS coupons

Simplified Single Lap Shear Strength coupons, manufactured with 4 plies stacked, isolating the load carrying area with Kapton film strips.



Test defined in: *Dreher P, Chadwick AR, Nowotny S. Optimization of in-situ thermoplastic automated fiber placement process parameters through DoE. In: Proceedings of the 40th SAMPE Europe conference; 2019, p. 1–13.*

AIMEN specimen after testing.



Annealing cycle

Half of the coupons were submitted to an annealing cycle:

Cooling rate of 10°C/min until 220°C.

Temperature of 220°C maintained for 90 min.

Cool down rate of 5°C/min until room temperature.

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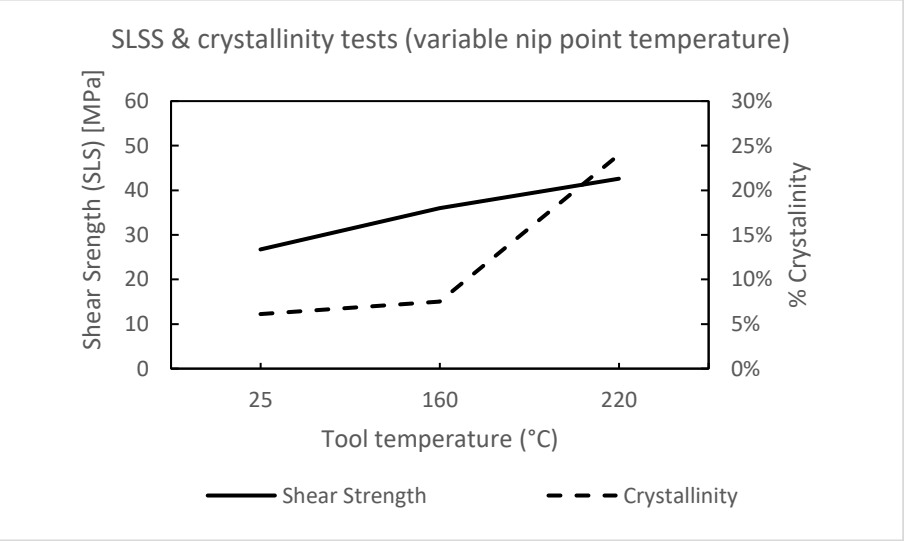
SLSS and DSC results

Coupons manufactured with tool temperature and nip point temperature **not** isolated.

Material properties of matrix.

Layup tool temperature [°C]	Nip point temperature (substrate) *1 [°C]	Crystallinity [%]	Shear Strength [MPa]
			Without Annealing
25	265	5.8	26.70±5.09
160	335	7.1	36.00±5.10
220	385	22.7	42.58±5.45

*1 Temperature measured at the substrate in the nip point area. The incoming tape was kept at a stable temperature of 350±15°C.



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Result discussion

SLSS and DSC results

Nip point temperature isolated from tool temperature. Laser power is controlled to achieve a constant nip point temperature.

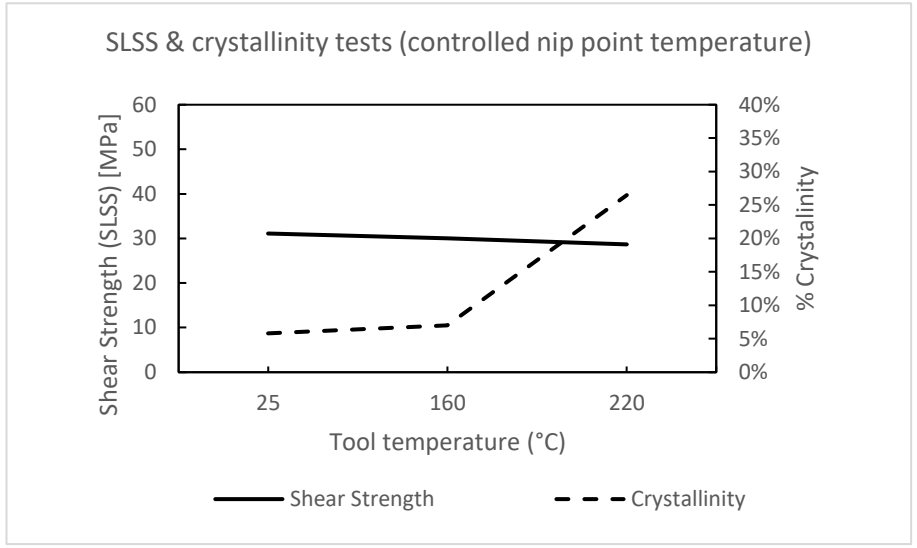
Material properties of matrix. Without Annealing.

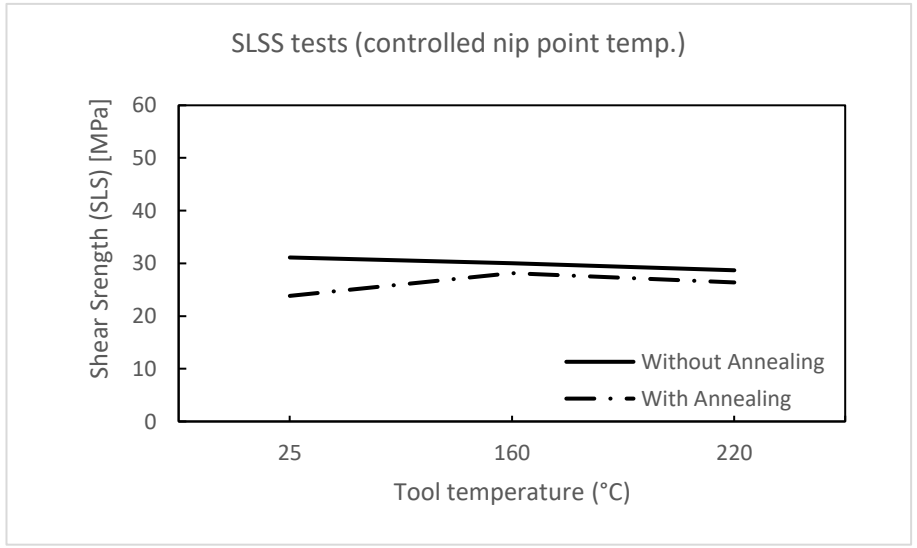
Layup tool temperature [°C]	Nip point temperature*[2] [°C]	Crystallinity [%]	Shear Strength [MPa]
25	330	5.8	31.11±4.85
160	350	7.0	30.00±3.37
220	360	26.5	28.67±1.77

Material properties of matrix. With Annealing.

Layup tool temperature [°C]	Nip point temperature*[2] [°C]	Crystallinity [%]	Shear Strength [MPa]
25	330	25.6	23.82±2.69
160	350	28.1	28.16±3.71
220	360	25.0	26.37±2.78

*[2] Temperature averaged from the substrate and the incoming tape in the nip point area.





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Conclusions

- There is a high influence of the layup tool temperature on crystallinity:
  - High tool temperatures (above the Tg of the polymer): high crystallinity percentages (around 25%) are obtained.
  - Tool temperatures below the Tg (147ºC): amorphous matrix (below 10% crystallinity)

- When the tool temperature influences the nip point temperature, it has a high influence on SLSS mechanical values. This shows that achieving a sufficient nip point temperature has a great influence on the interlaminar shear strength values (almost two times higher when increasing 120°C the substrate temperature at the nip point).

- When **isolating nip point temperature from tool temperature**, results show **no influence of crystallinity on SLSS values**.

- When isolating nip point temperature from tool temperature, results show **no influence when increasing crystallinity with annealing post-treatment on SLSS values**.

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Acknowledgements

This work is developed in DOMMINIO project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101007022.

Thank you for your attention

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