domminio

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

Newsletter

Issue #3, July 2023

Discover the Future of Aviation with DOMMINIO - Newsletter Edition #3

Welcome aboard as we soar into the 3rd edition of the DOMMINIO Newsletter, your gateway to the latest breakthroughs in aviation. Join us on an exhilarating journey into the world of the DOMMINIO project, where we are reshaping aviation systems through a cutting-edge Digital method for imprOved Manufacturing of next-generation MultIfuNctIOnal airframe parts.

At DOMMINIO, our devoted researchers are focused on developing an innovative data-driven methodology encompassing the design, manufacturing, maintenance, and pre-certification of multifunctional and intelligent airframe parts. Our vision is clear: to achieve cost-effective, efficient, and sustainable manufacturing of high-quality aircraft components, leveraging the following technologies:

- Robotic Technologies (ATL, FFF) for precision manufacturing
- Advanced Simulation Tools for optimized performance
- Online Process & Quality Monitoring for real-time insights
- Structural Health Monitoring (SHM) with data-driven fault detection capabilities

As we forge ahead on this transformative path, our newsletter proudly presents the findings from our latest milestone - "Functional Materials Engineering and Manufacturing Systems - WP3." Delve into the articles, insights, and discoveries shared here, and witness how DOMMINIO is shaping the future of aviation.

Stay connected with us through our website and join our vibrant social media community to remain up-to-date on the latest developments of the DOMMINIO project. Together, let's unravel the boundless possibilities that lie ahead for aviation systems.

Happy reading, and let's embark on this thrilling journey to redefine the future of aviation!!!

Pablo Romero Rodríguez

DOMMINIO Project coordinator

R&D Program Manager Advanced Materials & Manufacturing

aimen

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

Funded by the European Union

Let's connect

WP3 In a nutshell

In WP3, the materials to build the DOMMINIO demos were developed/selected and characterized. Those include the tapes to build the laminates and 4 different types of filaments to reinforce and functionalize the part (SHM and disassembly). As well, the operation windows to process the DOMMINIO materials by AFP, FFF, the combination of both, and the disassembly were optimized. Further, the data generated during the optimization of AFP and FFF was used to feed and validate the models in WP2.

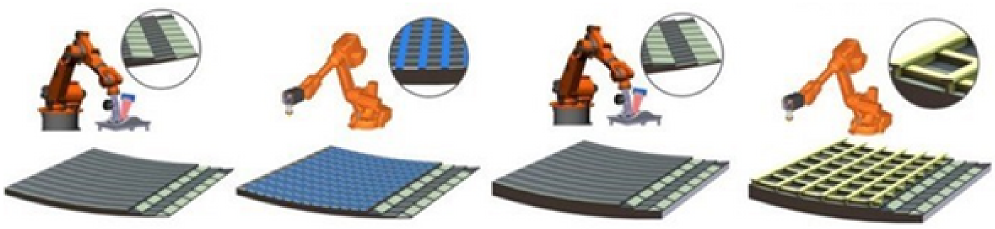


Figure 1*: Fabrication scheme combining AFP and FFF of the DOMMINIO demo*

WP3 Materials development and characterization

UD tapes: UD tapes based on LM-PAEK produced by TORAY (Jap).
Filaments: The four types of filaments for FFF used in DOMMINIO are:

a) an unfilled filament to build the reinforcements,

b) filament reinforced with continuous carbon fibre (cCF filament) for structural reinforcement,

c) filament reinforced with continuous carbon nanotube fibre (cCNT filament) for SHM purposes, and

d) filament filled with magnetic nanoparticles (MNP filament) for on-demand disassembly.

WP3 Materials development and characterization

The selected thermoplastic matrix for all the DOMMINIO filaments was PEKK:

1) Unfilled filament. Commercial unfilled filament of PEKK (60:40)

2) cCF filaments. Commercial cCF filament fulfilling the DOMMINIO specifications (PEKK matrix, CF aerospace grade, CF vol. fraction >40%).

3) cCNT filament. Filament fabricated in DOMMINIO. The CNT fiber has adequate linear density to keep it relatively easy to handle in the filament processing, but to exhibit the correct range of mechanical and piezoresistive properties in relation to gauge factor and sensing capabilities.

4) MNP filament. Filament fabricated in DOMMINIO. Different types of magnetic nanoparticles (MNP´s) based on Fe, Co and Ni were initially selected. Finally, the filament filled with Fe MNP´s at a concentration of 7.5% within the PEKK matrix was selected.

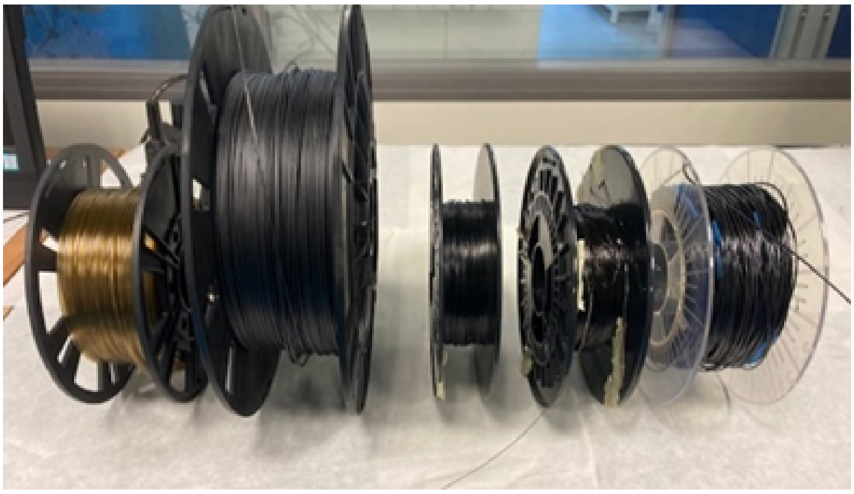
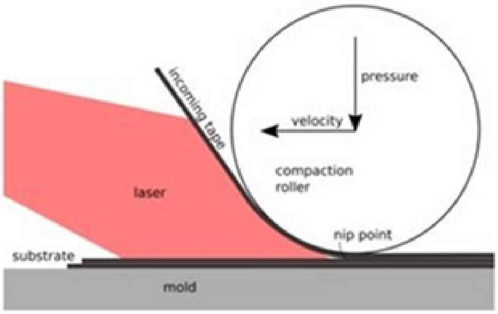


Figure 2: *PEKK Filaments used in DOMMINIO from right to left, filament with MNP´s, filament with cCNT, filament with cCF, filament with short carbon fibre and neat PEKK filament*

WP3 AFP Processing window

The optimization of the AFP process was based on four variables:

1. Nip point temperature
2. Lay up speed
3. Compaction force or pressure heated tool temperature



A DoE was set to quantify the effect of process parameters on the "simplified single lap shear strength". The best results were achieved when the Nip point temperatures are in the range of 390-425 °C, heated tool temperature between 150-220 °C, and pressure 400-500 N. The layup speed and the nip point temperature were found to be the parameters that have the major impact.

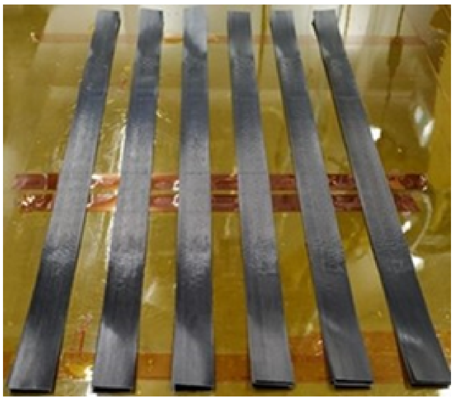


Figure 3: *Laminates produced by AFP for SLS testing*

The microscopic analysis of laminates (27 plies) produced with the optimized processing conditions showed void content less than 2%.

WP3 AFP Processing window

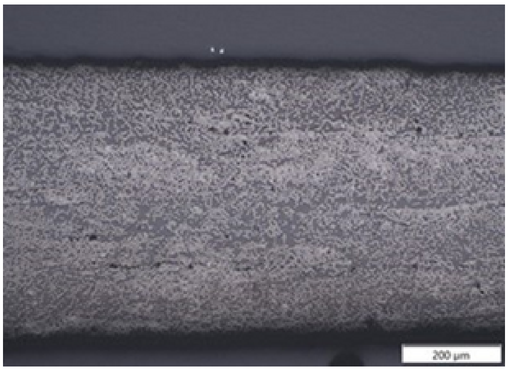


Figure 4: Cross section of UD laminate fabricated with the optimal parameters

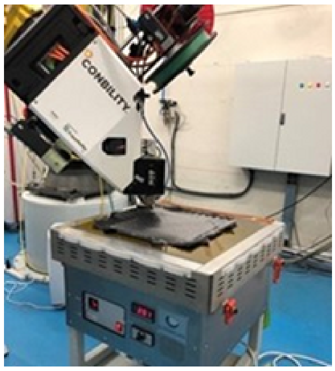


Figure 5: laminate being consolidated on a heated layup tool

The high required temperature to process the high-performance polymers used DOMMINIO brings important challenges related to the degradation of the silicone coating of the pressure roller. Additional temperature control is required to mitigate this effect.

Once optimized the AFP process, laminates were fabricated and the mechanical properties evaluated according to AITM1-007, ASTM D3030-17, and ASTM D3518-13 for tensile properties, AITM1-0008 for compression, and ASTM D2344 for ILSS. Data from those tests was used for the modelling activities in WP2.
The work in this task proved the feasibility of in situ consolidation by AFP of the DOMMINIO materials, though further improvements could be implemented in future work.

Issue #3, July 2023

WP3 FFF Processing window and combination of FFF and AFP

Printing trials with the selected TP matrix (PEKK (60:40)) were initially carried out on a desktop 3D printer with accurate control of the processing and environment temperatures, and in parallel, the robotized FFF process was optimized.

***Figure 6**: Desktop printer*

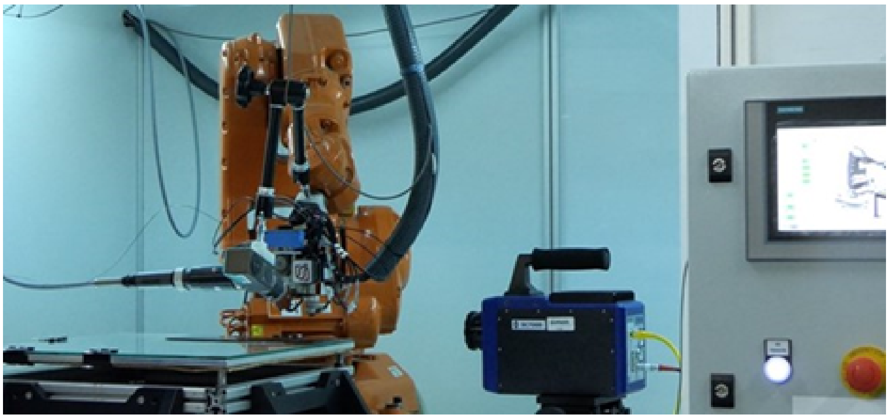


***Figure 7**: FFF robotized cell*

Though the less temperature-controlled fabrication environment in the large robotized cell, the resulting mechanical properties were found to be very similar to those achieved in the desktop printer, only 10% difference, and proves the benefits of using the slow crystallizing PEKK (60:40) for 3D printing in large robotized cells

WP3 FFF Processing window and combination of FFF and AFP

***Figure 8**: Robotized printing cell*

***Figure 9**: Detail of the printing head*

As expected, in the robotized cell the time between layer is critical to achieve good mechanical properties, especially in the Z direction. The use of additional heating sources (e.g laser) can help to compensate this effect, and reduces notably the anisotropy (resulting mechanical properties in the Z direction are approximately 80% of the correspondent values in X direction).

Samples fabricated with the PEKK filament reinforced with continuous carbon fibre and the aid of laser preheating, showed ILSS values between 70-80 MPa, and very low porosity, proving that is possible to 3D print true composites using continuous fibre reinforced filament.

***Figure 10**: ILSS samples fabricated with PEKK filament reinforced with continuous carbon fibre*

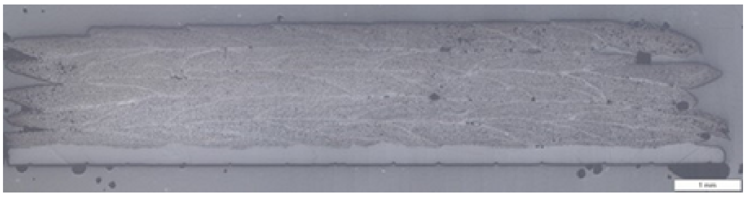


***Figure 11**: Cross section of a ILSS sample*

WP3 FFF Processing window and combination of FFF and AFP

In parallel to the optimization of the FFF processing window, samples in different configurations were fabricated with the cCNT and the MNP´s filaments to demonstrate the feasibility of printing those filaments and to supply samples for testing to T3.5 and the WP5 activities.

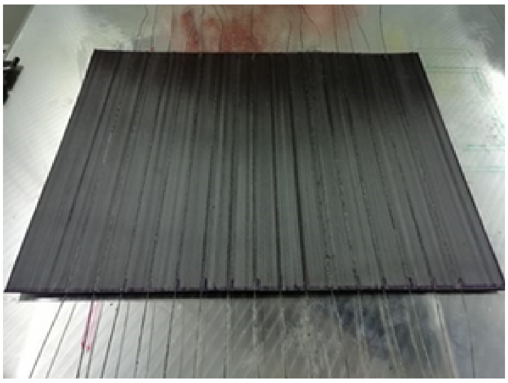


***Figure 12**: laminate with cCNT filament*

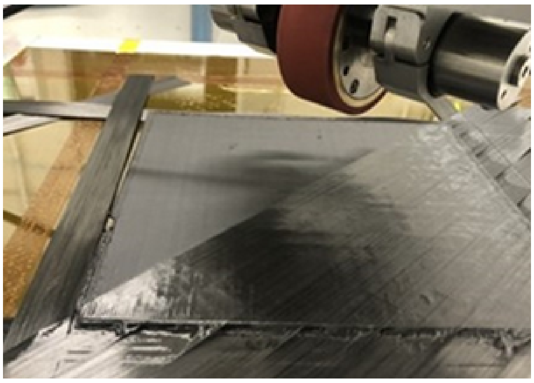


***Figure 13**: Sample with MNP filament*

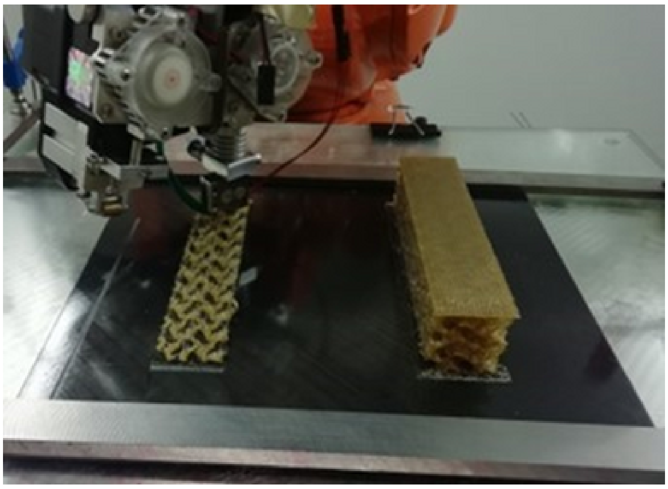


Figure 14: A first approach of the DOMMINIO demos was also fabricated, combining AFP and FFF.

Issue #3, July 2023

WP3 Disassembly Process window

The optimization of the disassembly process was based on the induction heating capacity of the “sandwich” specimens which was directly related to two key-factors:

·MNPs distance from the coil,

·The power of the generator,

Considering these two factors, the most successful outcomes were achieved when the debonding process was carried out at a 2 cm distance from the coil with a power of 4kW. At this setting, the temperature of the specimen reached and exceeded the melting temperature of pure PEKK polymer, thus facilitating disassembly

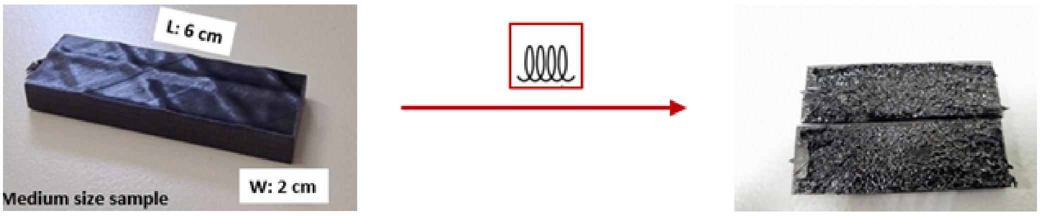


Figure 15: *"Sandwich" sample prior (left) and after debonding (right).*

WP3 Disassembly Process window

Furthermore, in this disassembly process window, a continuous "un-zipping" setup was developed, so larger specimens could be debonded. Five requirements were defined:

(i) Linear specimen movement below coil geometry, parallel to its longitudinal section,

(ii) Precise control of FFF interlayer-to-coil standoff distance. Modular design that enables to test different height positions (0.5 – 4 cm) with high repeatability,

(iii) Application of external load through a secured razor blade, aligned with the FFF nanocomposite interlayer of the specimen. Razor blade positioning at variable heights, in accordance with specification 2,

(iv) materials employed for all parts in close proximity to the coil should not be affected by the RF magnetic field, and (v) specimen holder with an embedded trench equal to specimen width trench height right below FFF interlayer and a protruding geometry to prevent specimen backlash during un-zipping

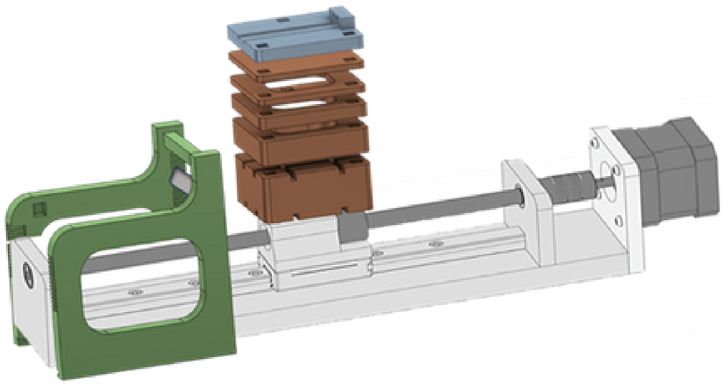


***Figure 16**: Final configuration of the experimental set up for continuous 'un-zipping.'*

WP3 Disassembly Process window

Additional optimization was conducted using specimens of 10.5 cm length and 2 cm width.

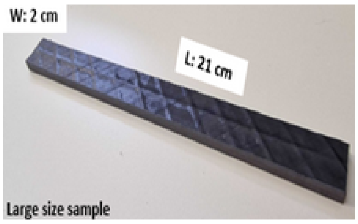


Figure 17: Large size specimen

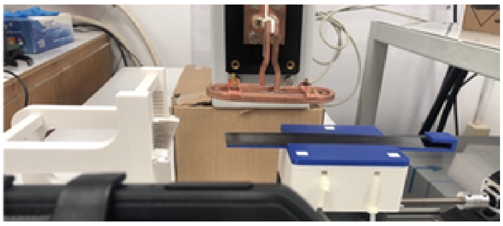


Figure 18: continuous un-zipping set up (right).

Experiments concluded that the most effective distance of the MNPs from the coil was 2 cm. Trials were conducted using different power levels ranging from 2 kW to 3 kW (0.5 kW step increase), and at all power values, the temperature exceeded 320˚C resulting to the melting of PEKK polymer. Subsequently, the specimens were shifted towards the blade, resulting in the debonding of all specimens regardless of applied power magnitude.

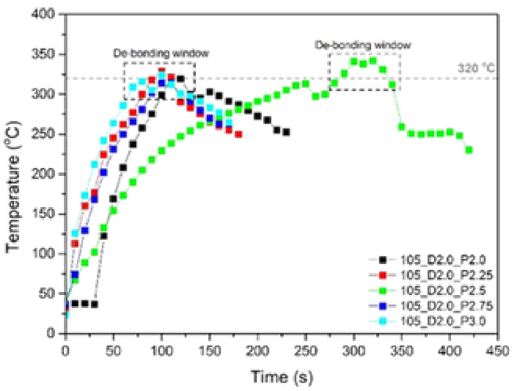


Figure 19: Induction heating temperature recorded during continuous debonding of 10.5 cm

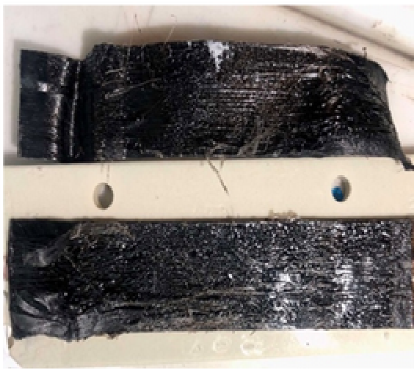


Figure 20: Induction heating temperature recorded during continuous debonding of 10.5 cm

Issue #3, July 2023

Digital method for imprOved Manufacturing of next-generation MultIfuNctIOnal airframe parts

Our Team

Connect with us