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

Newsletter

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Discover the Future of Aviation with **DOMMINIO - Newsletter Edition #5**

Welcome aboard on the thrilling adventure as we take flight the 5th edition of the DOMMINIO Newsletter, your portal to the most recent advancements in aviation. Immerse yourself in the fascinating realm of the DOMMINIO project, where we are transforming the aviation system 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 this transformative path, our newsletter proudly presents the findings from our latest milestone - **"Sensor development and SHM of multifunctional composite laminates - WP5."** 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!!!

WP5 In a nutshell

WP5 finished in December 2023, and was devoted to **developing Carbon Nanotubes (CNTs) sensors and a remotely-deployed digital twin** of a composite part. The work comprised experimental and simulation tasks.

To develop the **CNTs sensors**, IMDEA performed the characterization and calibration activities together with AIMEN; both partners worked on the embedding of the sensors.

The simulation activities carried out by IMDEA started with the set-up of an accurately correlated finite **element simulation of a flat composite panel**; this simulation was later used to train a digital twin that, thanks to the wireless node developed by INCAS, was deployed on a computer and fed remotely with the measurements from the embedded sensors to perform real-time damage detection.

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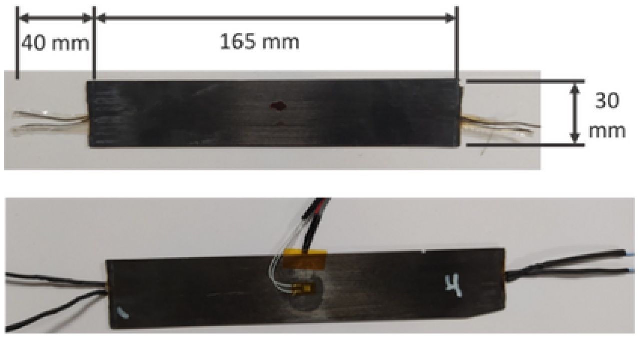
WP5 Sensor development and SHM of multifunctional composite laminates

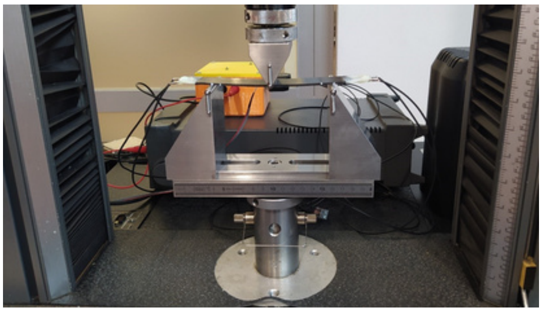
The activities performed in the WP5 were split into four tasks:

The first task comprised the development of **strain sensors** based on CNTs filaments, as well as the methodology for embedding the sensors in the composite part at the manufacturing stage. The sensors were first tested individually under unidirectional tension to ensure their viability as strain sensors. After that, a manufacturing process was developed that enabled their successful embedding in the panel while keeping the sensors accessible for their electrical connection.

***Figure 1**: (A) Dimensions of the coupon and fixation of the commercial strain gauges and (B) overview of the testing setup used for calibration of the embedded CNT sensors*

(A)





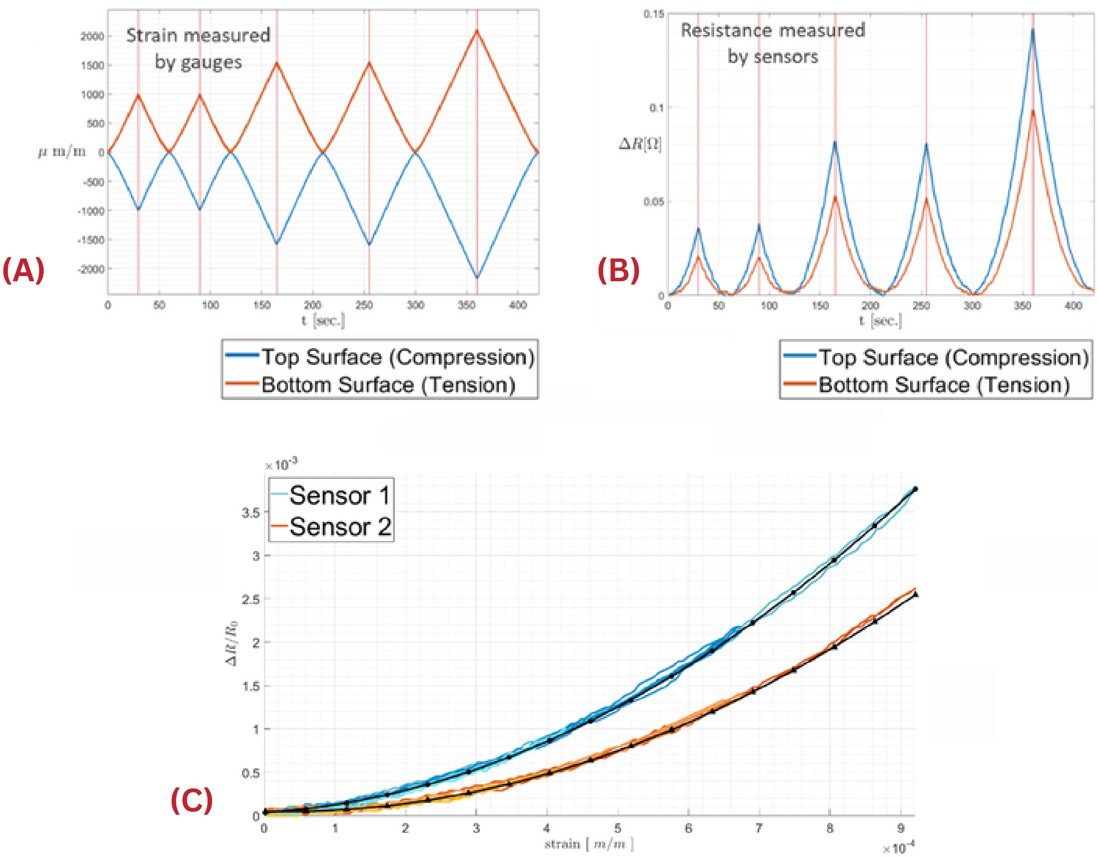
(B)

Once this was achieved, several batches of testing coupons were manufactured to calibrate the sensors. The calibration was performed by a **three-point bending test** of the coupons, instrumented with strain gauges in addition to the CNTs sensors (Figure 1).

During the tests, the strain at the center of the coupon was recorded at the same time as the resistance from the sensors.

With both values, it was possible to calibrate the change of resistance as a function of the strain experienced by the CNTs sensors (Figure 2).

***Figure 2**: Comparative analysis of the commercial strain gauges (A) with the embedded CNT sensors(B) in tracing the compressive and tensile deformations of the coupon. Quadratic fitting of resistance measured by CNT sensors as a function of experimented strain (C)*



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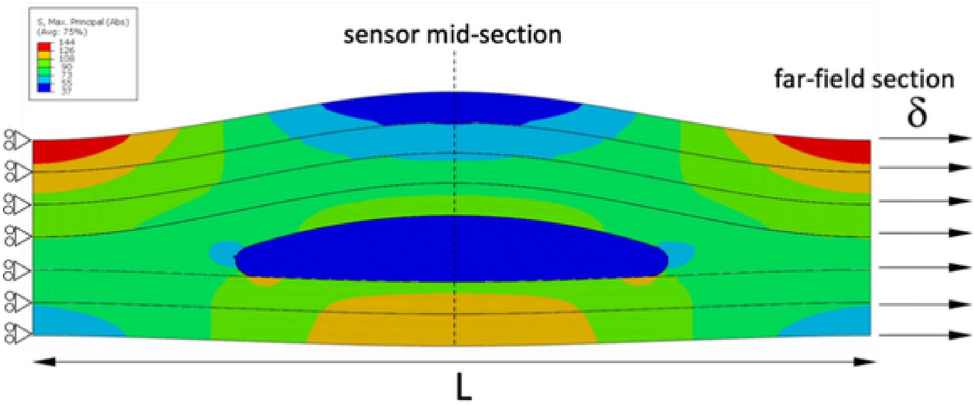
The second task was devoted to the development of the multiscale modeling representation.

For the microscopic scale, it was developed a finite element model for the interaction of the embedded CNTs sensors with the surrounding layers of carbon fibre composites;

This model made it possible to assess the distortion effect of sensors in airframe parts, gaining insight into its local effect on internal stresses (Figure 3).

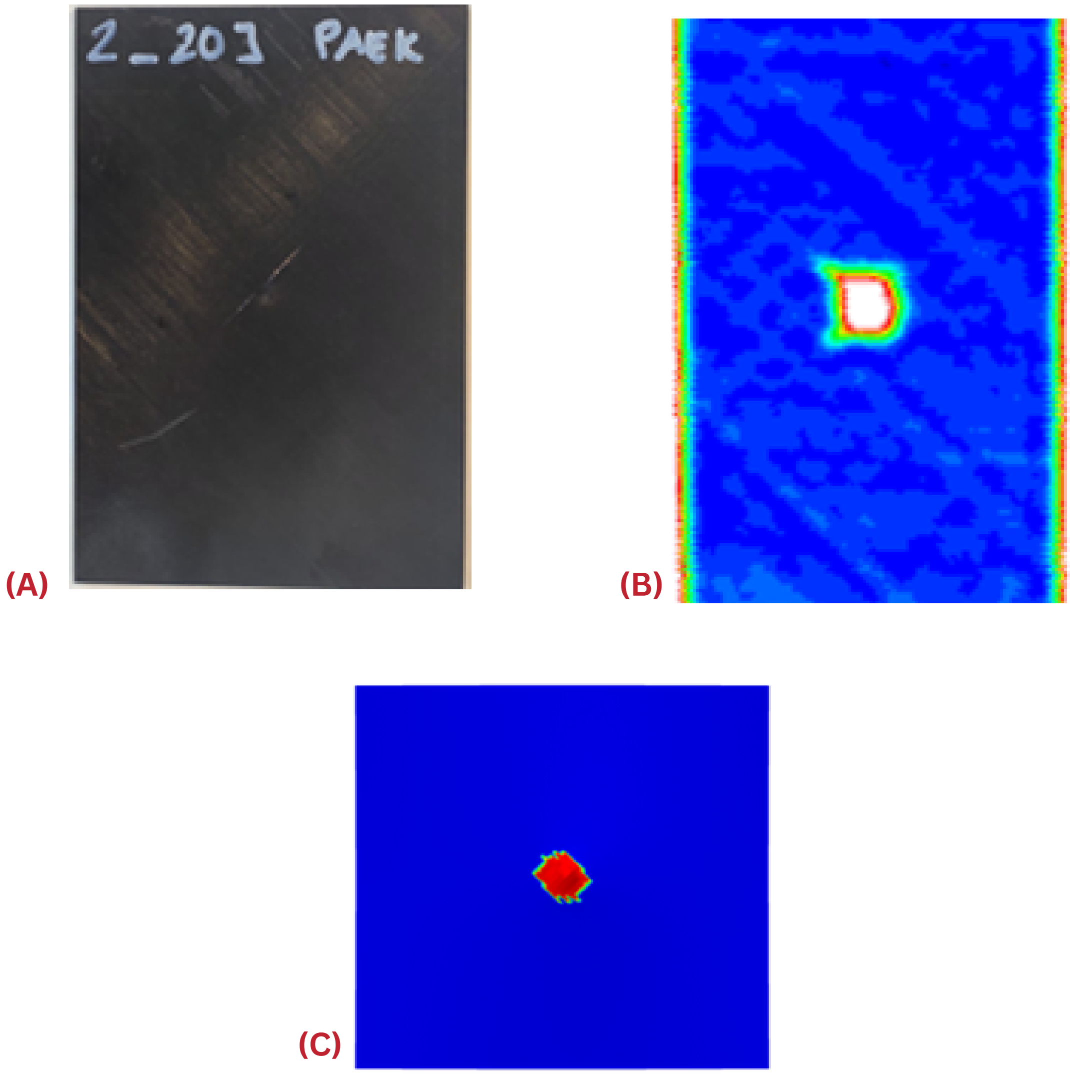
***Figure 3**: Microscopic model's prediction of principal tensile stresses in the laminate with an embedded CNTs sensor(between plies 3rd and 4th from the bottom), subjected to uniform strain in the horizontal direction*



In addition to this microscopic model, a **finite element simulation of the entire panel** was used to capture all the needed features efficiently, enabling the training of the artificial intelligence algorithm used in the digital twin in the third task.

Since capturing accurately the effect of impact damage is critical for structural health monitoring applications, the model was correlated with low-velocity impact (LVI) experimental tests (Figure 4).

***Figure 4**: A) [±45°,0°, ±45°,90°]2s panel subjected to low velocity impact (LVI) of 20J, (B) Ultrasound inspections of the LVI tested specimen, (C) Delaminated area in the back -45/0 interface in the simulation*



The third task comprised the development of a digital twin for a composite panel with embedded sensors, including the calibration of the model to represent the physical asset and an artificial neural network trained to detect and locate impact damage.

The panel was instrumented with an array of strain gauges and CNTs sensors (Figure 5A) and impacted with energies of 3J and 5J.

(A)

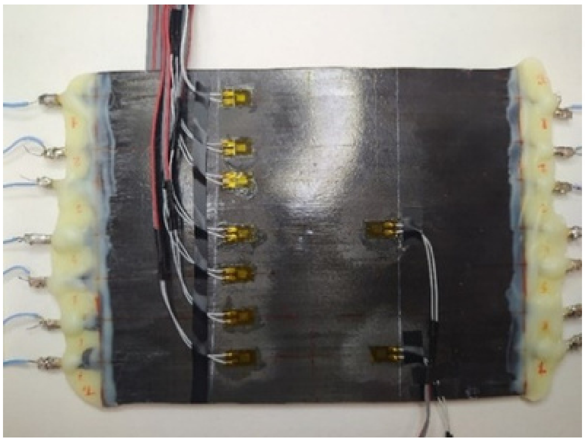
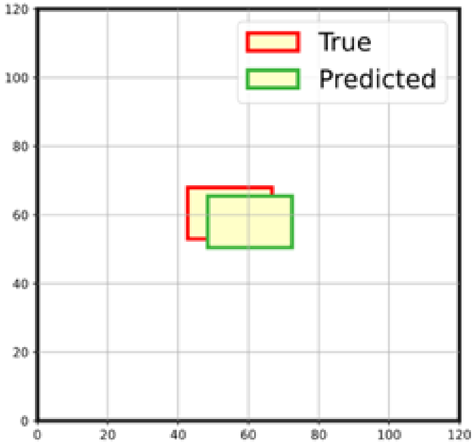


Figure 5: A) Panel after 5J impact and (B) predicted position of damaged region by digital twin compared with actual damage detected by ultrasonic inspection



(B)

Using the array of sensors, it was possible to calibrate the computational model to reproduce experimental strain accurately.

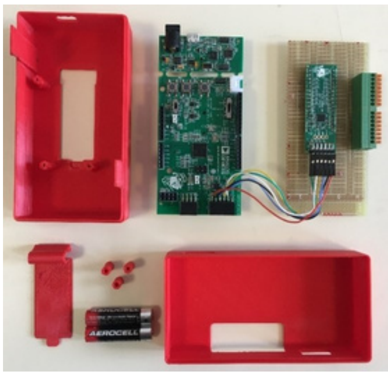
The model was then used to generate a synthetic dataset on which **the artificial neural network was trained**, taking as inputs the signals from strain gauges and successfully predicting the position of damage as well as the impact energy (Figure 5B). At the same time, the measurements from CNTs sensors were used to know the bending strain in the panel.

The work carried out in the fourth task delivered the wireless module to be connected to the array of sensors (Figure 6).

The measurements from sensors are recorded by this module, which then sends them via Bluetooth to a remote central computer that can store these data, **collecting information from several instrumented parts**. All this data is sent further to a cloud server in which the digital twin was deployed, performing the health monitoring (Figure 7).

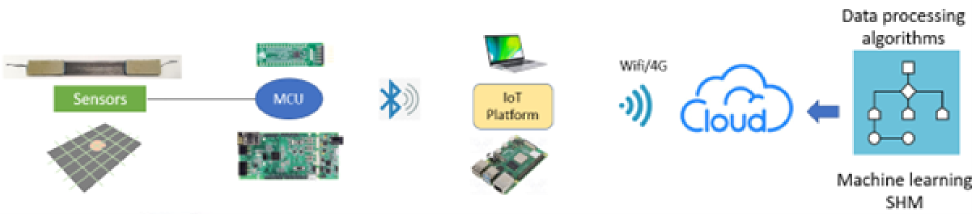
Figure 6*: Wireless transmission module. Main components (A) and assembled product (B).*

(A)



(B)

Figure 7*: General concept of the wireless sensor network.*



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