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INFINITE

Aerospace composites digitally sensorized
from manufacturing to end-of-life

D3.3
Manufacturing of sensorized composite component

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INTRODUCTION

INFINITE Project has focused manufacturing processes based in the usage of dry multiaxial NCF (Non crimped fabrics) to produce structural components for aerospace industry. Among the different options with these same features, liquid resin infusion (LRI) has been selected as the target process for the incorporation of resin to the dry preforms. This method is widely used for aeronautic components because it enables high production rates in components with great mechanical properties without the need of a accurately controlled environment (Boisse & Hamila, 2021; Zheng, 2024). In the stage prior to adding the matrix, the process involves shaping the initially flat dry fabrics to geometries that are difficult to reproduce by the fabrics. Especially, the NCF, which has great mechanical properties for aeronautic applications but worse drapability. During this phase, heat and pressure are applied to the fabrics and defects (wrinkles, voids...) can be created. That would compromise the validity of the final part and for that reason, it is of major importance the validation of the fabrics before the infusion.

To achieve this objective, the Teijin NCF fabric with MW was characterized to implement the properties in simulation software. With the calibrated properties, the design of the demonstrator has been made as to produce defects during the manufacturing in the form of wrinkles.

The level of development of INFINITE monitoring technology remains at the end of the project at low TRL (Technology Readiness Level), which makes it difficult to monitor all manufacturing steps. This demonstrator aims at checking the feasibility of an automated monitoring system based in INFINITE solutions applied to the different manufacturing steps necessary to produce from raw dry NCF to infused and cured complete structural parts, with the current limitations of the technology at the end of the project.

The basics behind the definition of the demonstrator are:

- It is representative of the aeronautic manufacturing procedures
- It allows being monitored along all manufacturing stages
- The monitoring doesn't affect or interphere the development of the manufacturing process
- Monitoring can be caried out in real time

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DESCRIPTION OF THE DEMONSTRATOR

The aim of this demonstrator is to assess the validity of the technology developed within the INFINITE project. To that end, a manufacturing process will be monitored in sequential steps using the latest version of the readers developed by RISE. The steps are as follows:

1. Cutting
2. Laminating
3. Preforming
4. Infusion
5. Curing

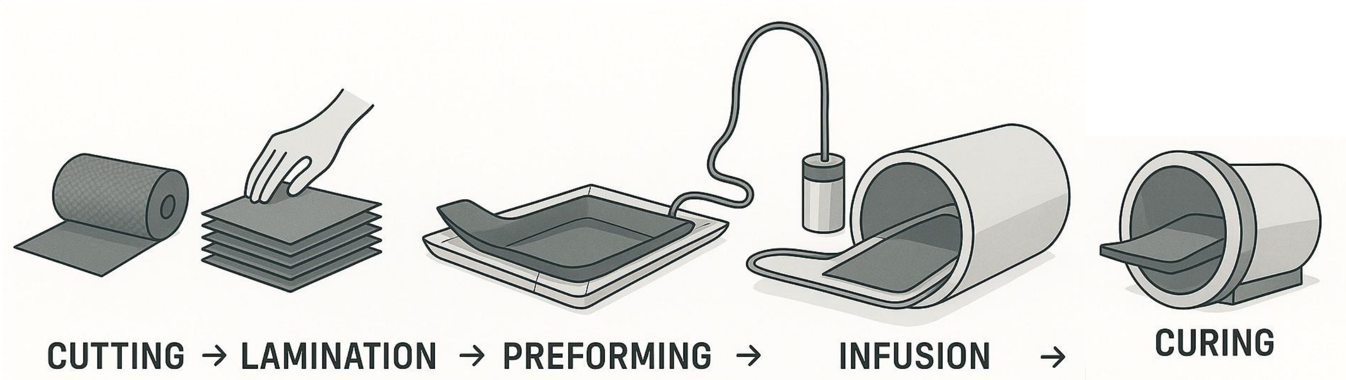

Figure 1. - Manufacturing steps

It is important to monitor several areas of the part during the process. This requires precise measurements in target areas, even as their positions shift throughout the process. To enhance precision and enable automation, the reader will be mounted on a KUKA LBR iiwa robot.

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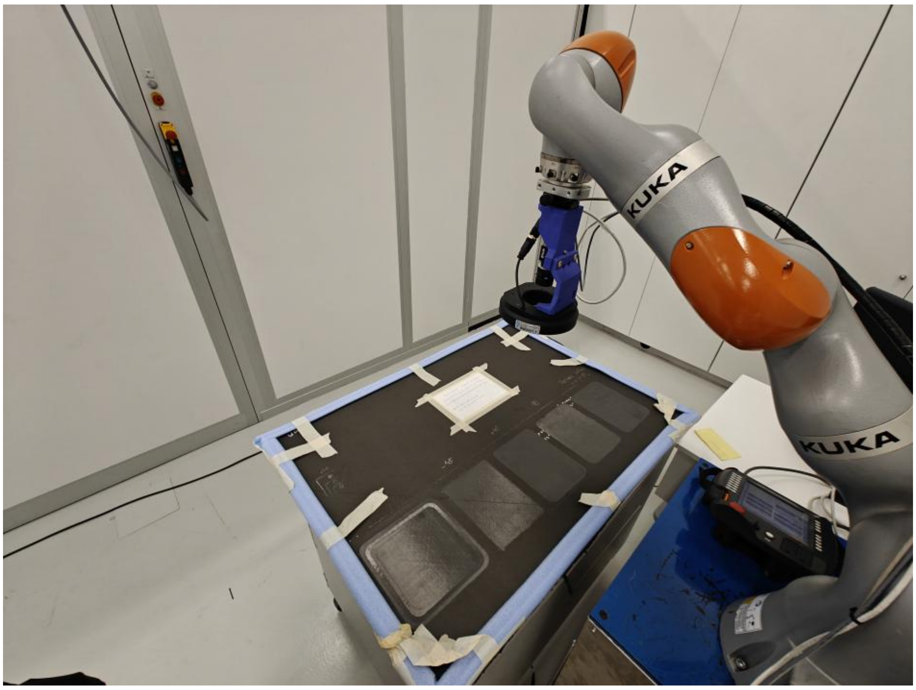

Figure 2. - Robot for automation of monitoring operations

Given that the primary goal is to detect potential defects during the manufacturing process, this demonstrator has been designed such that wrinkles are supposed to occur during the preforming phase of the infusion process. To evaluate the effect of these wrinkles on the MW and the resulting measurements, it was necessary to intentionally induce a defective scenario.

To this end, the dry fabrics were first characterized, and then a finite element (FE) simulation was used to replicate such a condition. Two experimental tests were conducted to determine the in-plane and out-of-plane mechanical properties: the picture frame test and the cantilever test, respectively. The FE material model was calibrated based on the results of these tests. A spherical dome with a flat area on top was selected as the forming tool, as prior experience has shown that this geometry tends to produce wrinkles.

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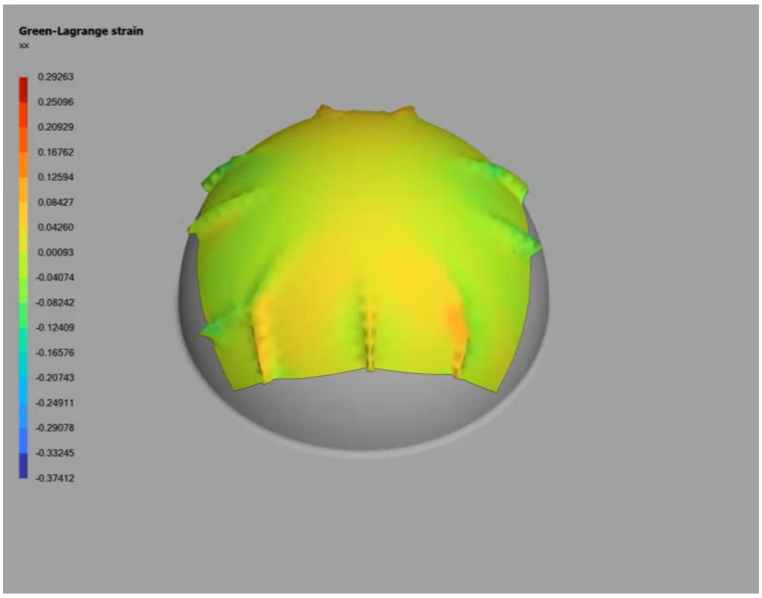

Figure 3. -Simulation of forming and drapping of fabric

The selected tool consists of a hemispherical dome with a 270 mm diameter and a flat area located at 130 mm height, ensuring that at least one measurement area is not affected by curvature. The tool is made of glass fiber and coated to prevent porosity

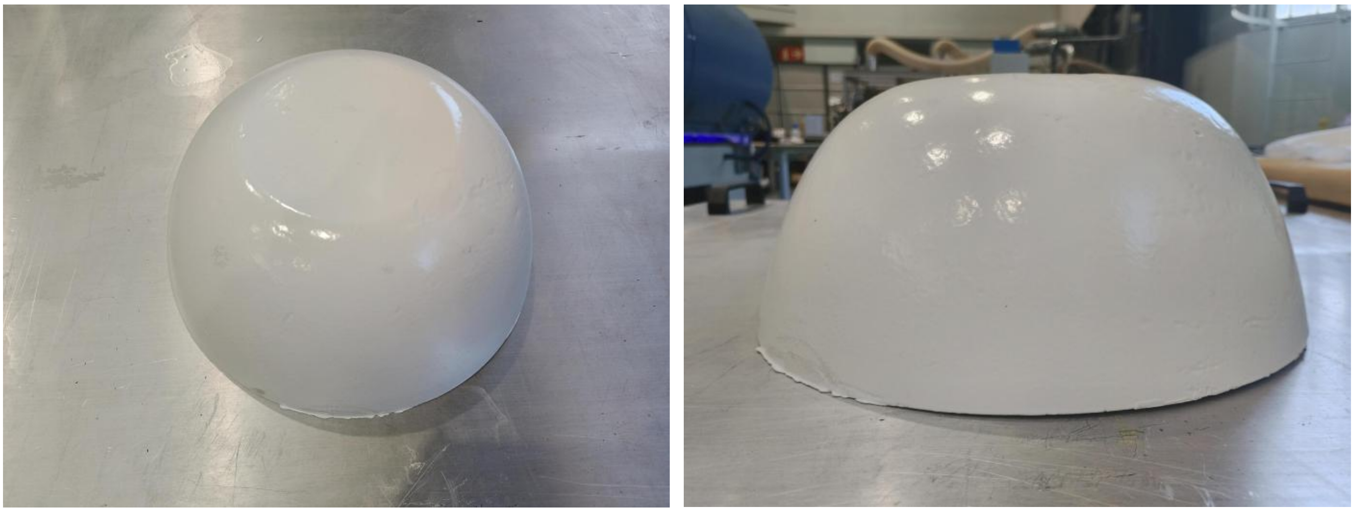

Figure 4. -Tooling

A single fabric was selected, assuming typical friction values against the tool surface. The dry fabric is cut into a 270 mm diameter circular shape to cover the entire geometry. Before it is placed onto the tool, while still flat, the measurement areas of interest are marked. One of these areas is at the centre of the circle, which will remain flat after preforming. Eight additional points are marked at 45° intervals in polar coordinates, at a radius of 80 mm. During measurement, the relative orientation between the reader and the MW signal will be maintained.

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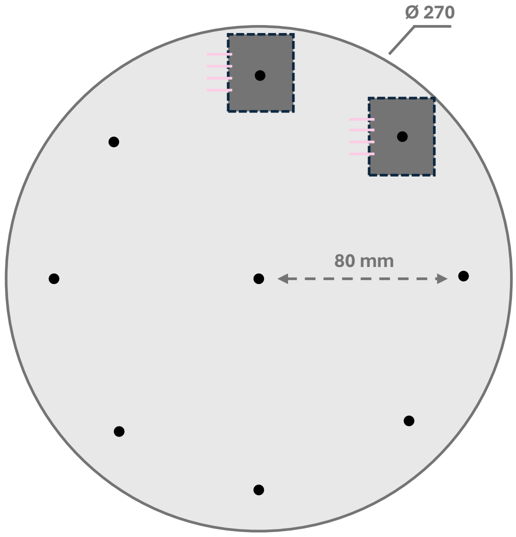

Figure 5. - Control points in the flat geometry

After shaping the flat fabric to the tool, the new positions of the measurement points must be redefined. This will be done by performing several repetitions to locate the resulting point cloud. These 3D coordinates will be programmed into the robot to ensure accurate positioning of the reader for measurements during the preforming phase.

To infuse the dry fabric, the setup will include a resin inlet positioned along the perimeter of the base, oriented at 45° and centered on the left side of the schematic. A valve will be placed on the opposite side to act as the air outlet. As soon as the resin begins to flow inside the vacuum bag, the robot will move to the predefined positions, repeating all measurements every 30 seconds. A custom script will be developed to instantly capture the signal’s height and peak values, and the evolution of the parameters over time will be plotted in real time.

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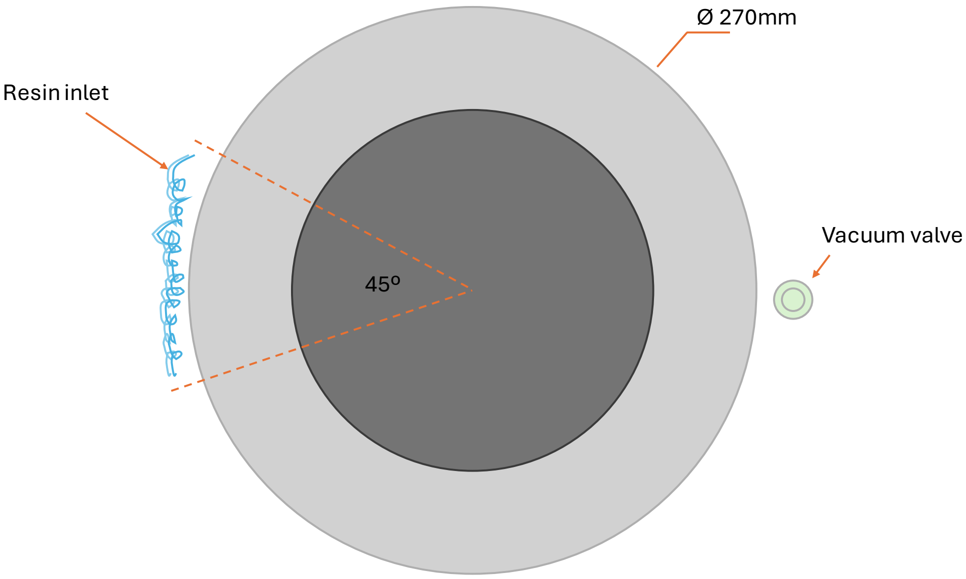

Figure 6. - Distribution of elements for infusion

Once the infusion is completed, the resin injected to the part needs to be cured. For the sake of simplicity, a room temperature curing epoxy resin will be selected. This way the reader can be in contact with the part and no distortions in the signal from electric heaters are expected. The readings will be taken every 3' in the first 60', and every 30' for the rest of the day.

The following table summarizes the developed methodology to automatically monitor a manufacturing process of a composite.

Lamination	2D	9 areas	1 measurement in total
Preforming	3D	9 areas	1 measurement in total
Infusion	3D	9 areas	1 measurement / 30''
Curing	3D	9 areas	First 1h→ 1 measurement / 3' Rest day → 1 measurement / 30'

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BIBLIOGRAPHY

Boisse, P., & Hamila, N. (2021/). Modeling composite reinforcement forming processes. In *Composite Reinforcements for Optimum Performance* (or. 671–691). Elsevier. https://doi.org/10.1016/B978-0-12-819005-0.00021-6

Zheng, R. (2024/). *Draping of biaxial non-crimp fabric on hemispherical shape*. 623–630. https://doi.org/10.21741/9781644903131-69