NOVEMBER 2021 | ISSUE 2

AIRPOXY

# NEWSLETTER

**AIRPOXY's primary objective is to reduce the production and maintenance costs of composite parts in the aeronautics sector through the introduction of a novel range of innovative thermoset composites retaining all the advantages of conventional thermosets, while also allowing for easy processing, repair, and recycling.**

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### Sharing results & preparing future exploitation

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# Development of 3R-Thermoforming technologies

After the 3R resin formulations were further improved and the processing in infusion processes (RTM - Resin Transfer Molding) and continuous prepreg processes were finally validated, good results were also achieved in the thermoforming of fully cured, carbon fiber-reinforced 3R laminates. For this purpose, thermoforming processes such as continuous compression molding (CCM) and discontinuous compression molding (DCM) were investigated on a laboratory scale.

Different consolidation concepts, process parameters and input materials were examined. This gained results were compiled into guidelines for the manufacturing of the demonstrator parts using the thermoforming process in industrial scale production. A significant finding in the case of DCM is that despite the high matrix viscosities of the carbon fiber-reinforced 3R laminates, void-free thermoforming components (figure 1) can be obtained. For this purpose, processes and geometries have to be adapted, in order to achieve additional interlaminar shear during forming. With regard to the CCM process, it was shown that both continuous laminates and omega profiles (figure 2) can be produced from stacked, semi-cured, impregnated single fabric layers after consolidation at temperature (T = 200°C). In addition to process development and related parameter studies, mechanical characterization of the 3R-laminates is almost completed. The interim results are shown in the table.

Some Results of the mechanical characterization performed:

| Reinforcement | Properties | Unit | Results |
|---|---|---|---|
| 5HS Fabric 6K (0º/90º) layers | Tensile Properties | MPa | 1.060 |
| | Compression Properties | MPa | 531.4 |
| | Shear Properties | MPa | 79 |
| | Interlaminar Shear Strength | MPa | 54.0 |
| | Fracture toughness | J/m2 | 620.4 |
| 5HS Fabric 6K Quasi isotropic laminate | Open Hole Tension | MPa | 512.0 |
| | Open Hole Compression | MPa | 276.1 |
| | Filled Hole Compression | MPa | 371.6 |
| | CAI | MPa | 181.6 |
| | Bearing | MPa | 862 |
| | Interlaminar tension Strength | MPa | 28.95 |
| | Pull-Through Strength | MPa | 105.5 |
| | Fatigue - stress level for 10K cycles | MPa | 426 |
| | Fatigue - stress level for 100K cycles | MPa | 304 |
| | Fatigue - stress level for 1M cycles | MPa | 244 |

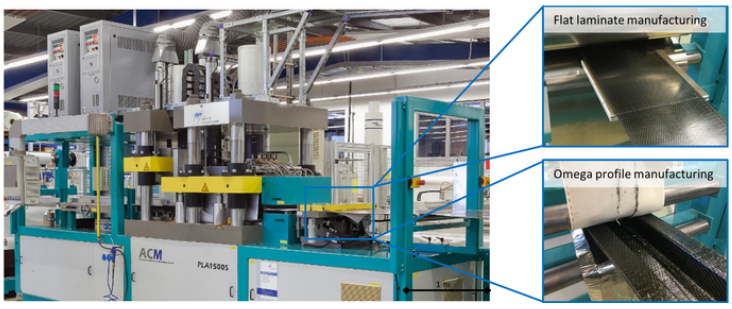



Figure 2: Continuous compression molding (CCM) at IVW GmbH

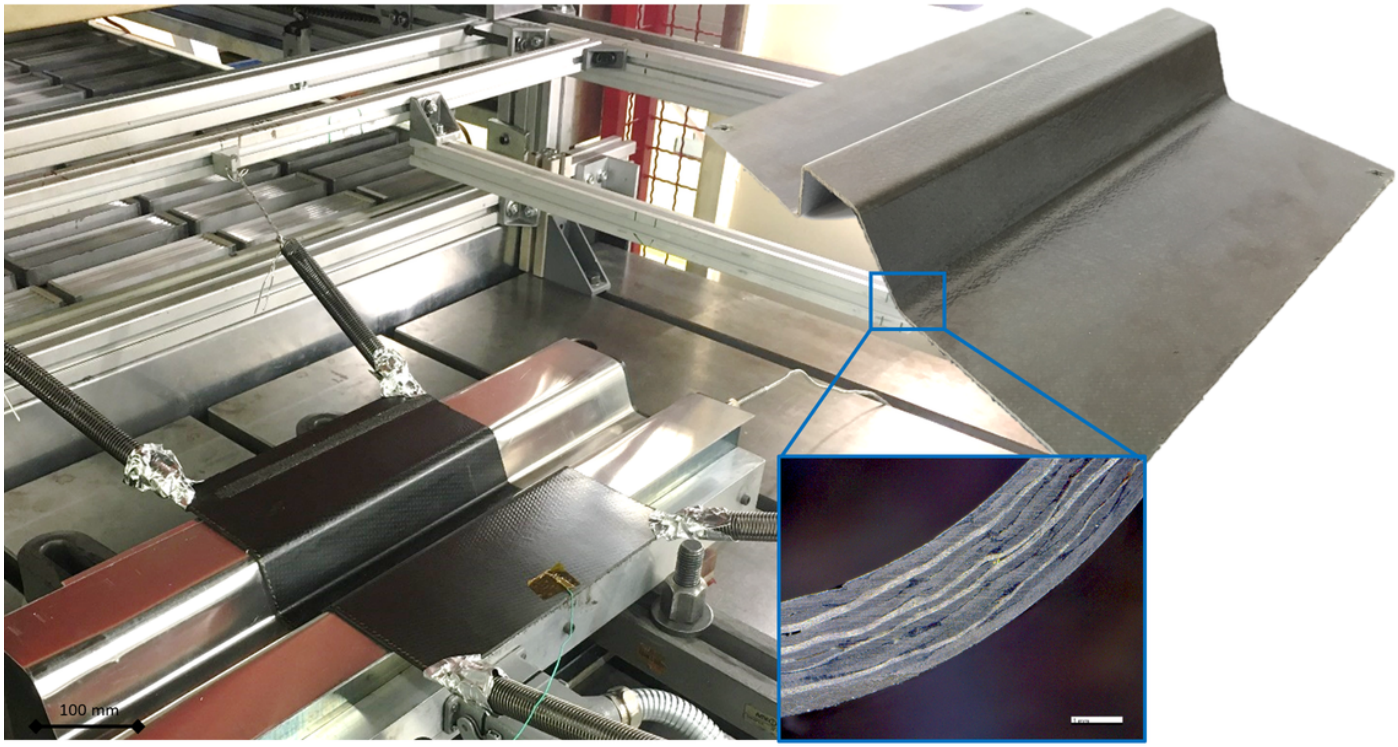
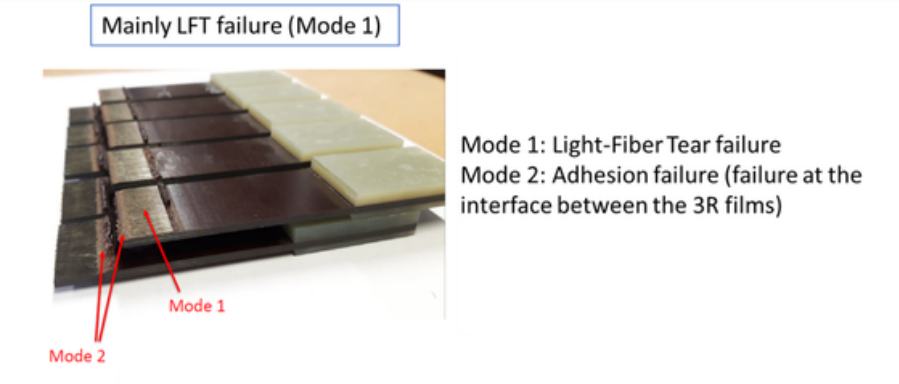



Figure 1: In DCM thermoformed 3R-laminate after heating by IR and consolidation at forming temperature in the closed mold at IVW GmbH

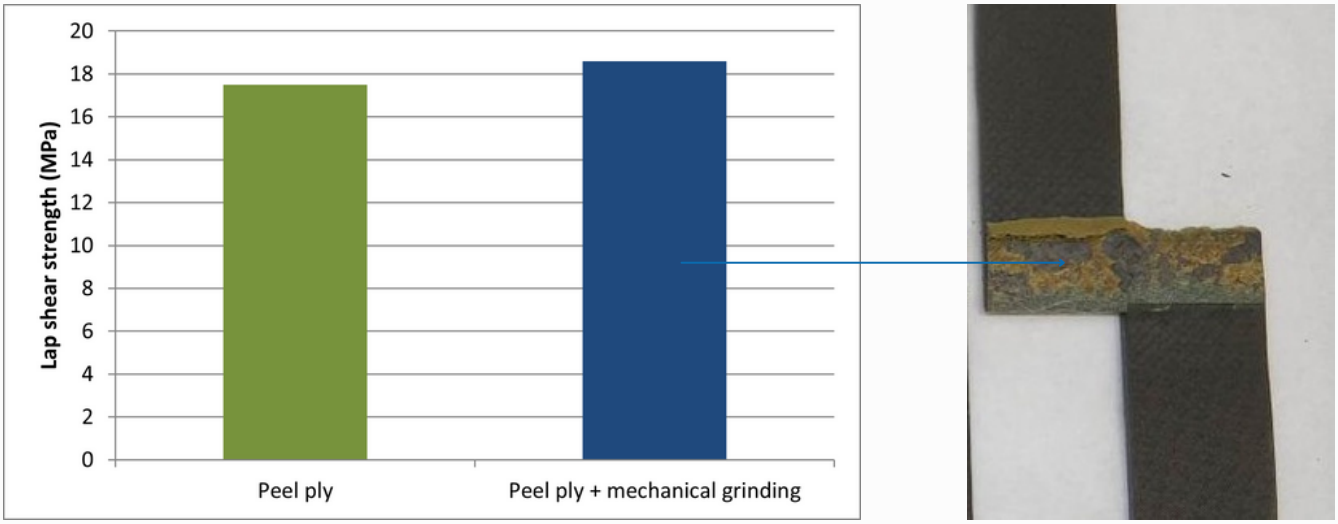
# Development of 3R-Bonding technologies

The main objective of this work package is to develop the bonding processes for 3R composite laminates, with two possible variants being studied: adhesive bonding and welding. Both adhesive bonding and welding processes have been studied and optimized. Bonding processes and tooling's for 3R adhesive bonding and 3R welding have been defined and design.



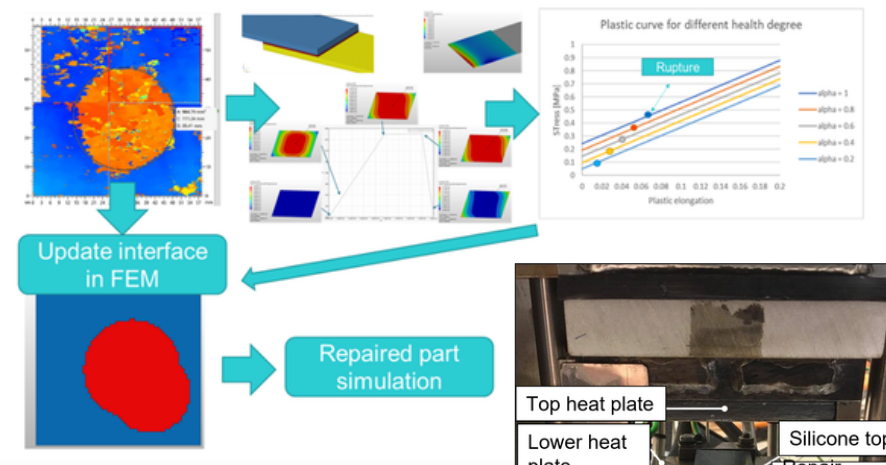

Failure mode of welded SQRTM substrates (SLS of 17.7 MPa)

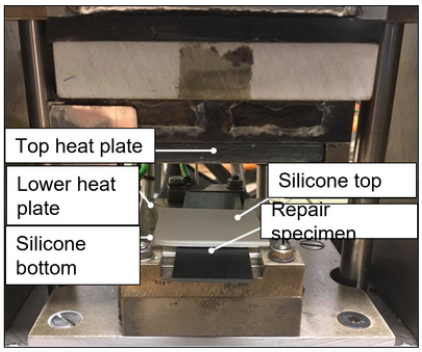
Related to adhesive bonding, CIDETEC has manufactured and characterized 3R adhesive film (AIR-ADH-22) for the Project. The handling and application of 3R adhesive film has been finished and guidelines for its application in WP5 have been produced. A lap shear of 20 MPa has been achieved. The defined guidelines will allow adhesive users (IDEC) to identify options for quality assurance for their applications and to select suitable methods. Previously, EURECAT has performed the RTM process parameters optimization for the manufacturing of the 3R laminates. Regarding welding activities of 3R panels, COEXPAIR has defined the process parameters to manufacture SQRTM panels having a weldable surface. IVW has defined guidelines to successfully weld 3R laminates by conduction welding. Finally, SONACA has performed the inspection (visual, NDT, micrography) and characterization of welded SQRTM panels. The welding results are compared with co-cured panels and secondary bonding results. A lap shear strength of around 18 MPa has been achieved in welded specimens. Complete mechanical characterization of welded parts is on-going and it is expected to finish by June 2022.
In the numerical side, a detailed material law and modelling approach for 3R adhesive have implemented for both implicit and explicit solvers by ALTAIR. This allows users to study a wide variety of cases: quasi-statics, dynamics, impact, crash...
The obtained results and knowledge will be transferred to WP5, to manufacture the project demonstrators.



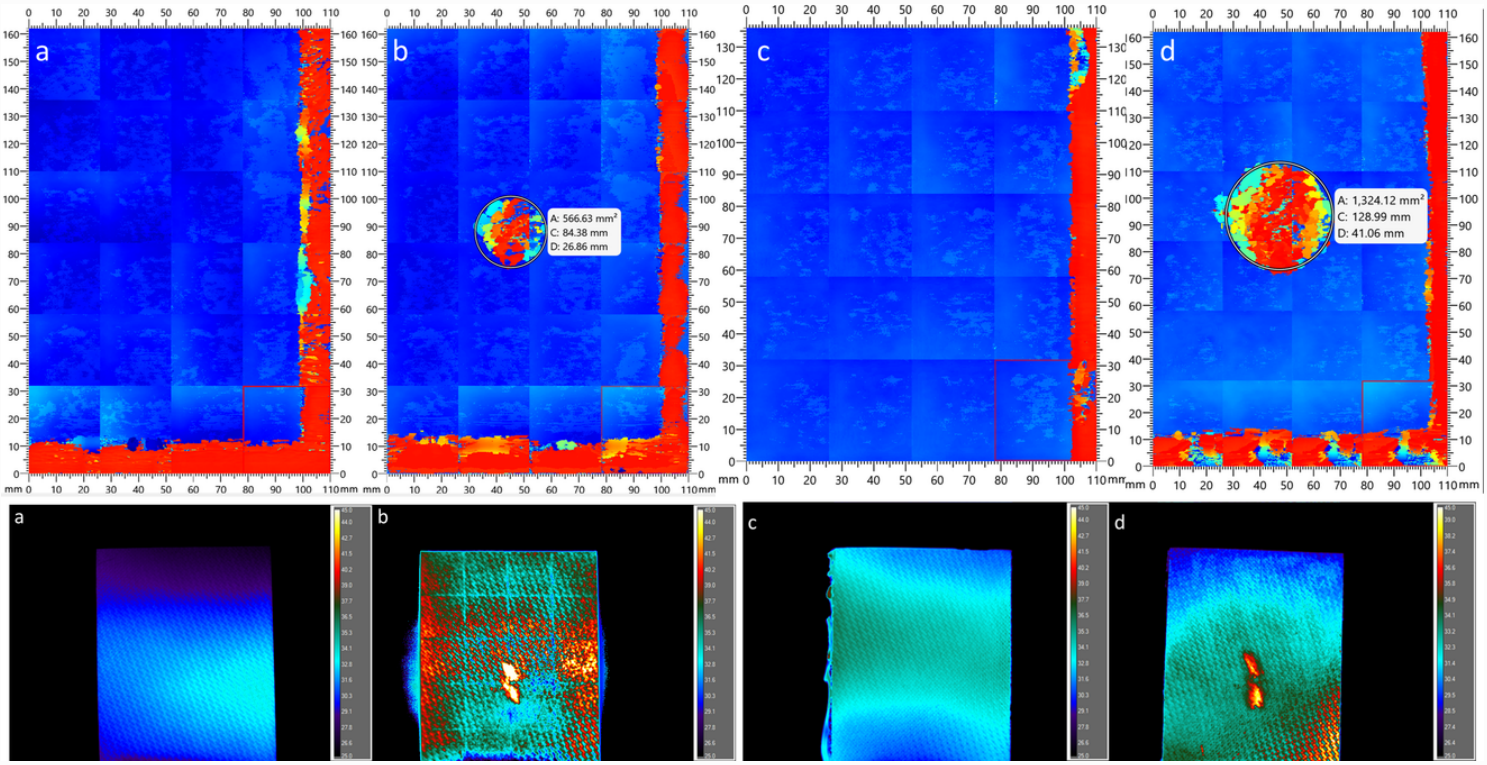

Lap shear strength of adhesively bonded 3R substrates with different substrate treatment

# SHM and development of 3R-Repair technologies



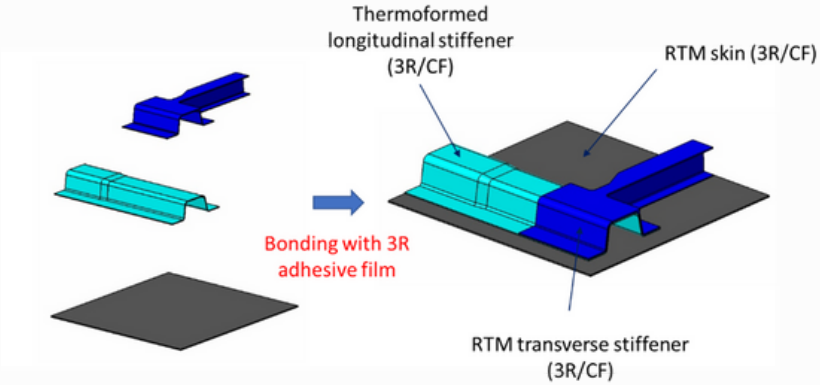

The work concerning structural health monitoring and development of 3R-Repair technologies was successfully finished. The first achievement was the knockdown effect assessment between the 3R and the conventional (RTM6) composites via mechanical and non-destructive testing. A very negligible knockdown effect of about 3-4% was calculated, proving that the 3R resin had similar mechanical properties with the conventional (RTM6) resin, that is a typical aerospace graded resin. The same tests were performed at 3R composites manufactured by different production processes, such as the RTM process, the thermoforming process using the 3R enduring prepregs (EPP's) and the SQRTM process, in order to evaluate their differences and the repair efficiency. All the repair investigations and the processes were performed by IVW. A repair efficiency from 70% to almost 100% was achieved in different geometries. ALTAIR, simultaneously, exploiting all the experimental results, performed all the simulations on repair with the development of a repairing model and determined the change on mechanical response.

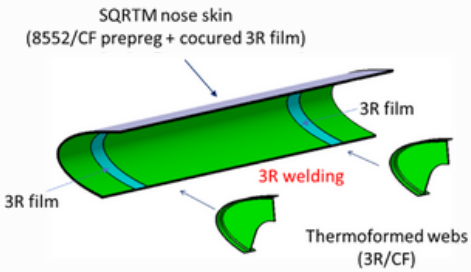


# Validation of technologies in industrial environment

This work package aims at validating the technologies developed in AIRPOXY on demonstrators within an industrial environment. Two demonstrators which are subcomponents of real aircraft structures (fan cowl and leading-edge) have been designed. The demonstrators exhibit several complex design features: the fan cowl demonstrator includes a complex RTM transverse stiffener, an omega-shape longitudinal stiffener with a cross-section variation and a change of thickness that shall be thermoformed and a complex bonded assembly with 3 elements ; the leading-edge demonstrator includes a SQRTM skin with a mix of conventional and 3R materials, highly double curved webs that shall be thermoformed and a complex webs-to-skin welded assembly.

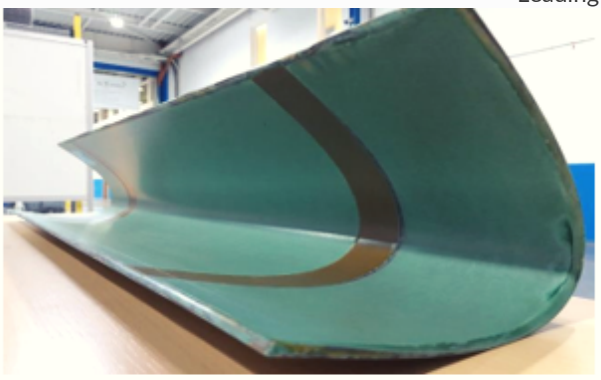
Most tools for the manufacturing of the demonstrators have been delivered now and the manufacturing of elements has started. For the fan cowl demonstrator, 2 skins and 3 transverse stiffeners were successfully manufactured by RTM using 3R resin and carbon fibers, and 7 longitudinal stiffeners were thermoformed with a press from fully cured 3R/CF RTM flat laminates. After an optimization of the process parameters, longitudinal stiffeners with a good surface quality and no wrinkles were produced. The bonding of the 3 elements with a 3R adhesive film will start in the coming weeks. For the leading-edge demonstrator, 4 nose skins were successfully manufactured by SQRTM. These skins are made of conventional 8552 prepreg with a 3R film cocured at the inner surface to allow for the welding of the webs. Some trials for the thermoforming of the webs made of carbon fibers reinforced 3R resin have started and first results obtained by thermoforming a fully cured 3R/CF RTM flat laminate are promising.

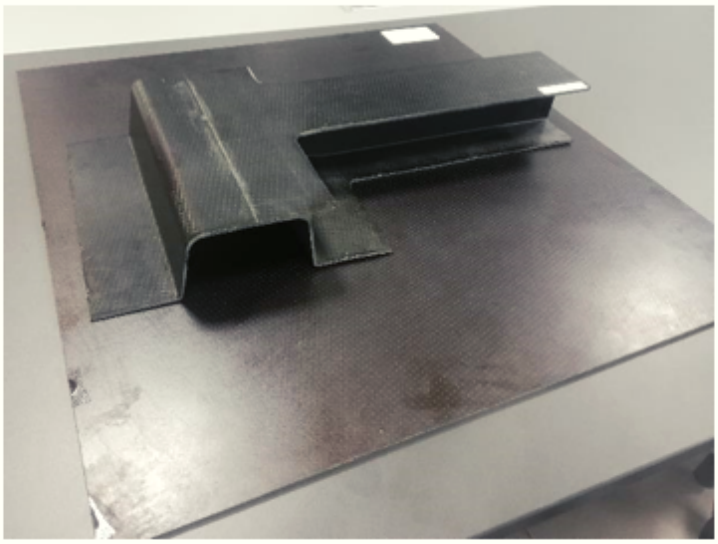



Fan cowl demonstrator (designed by IDEC - photo credit: IDEC)

Leading edge demonstrator (designed by SONACA - photo credit: SONACA)

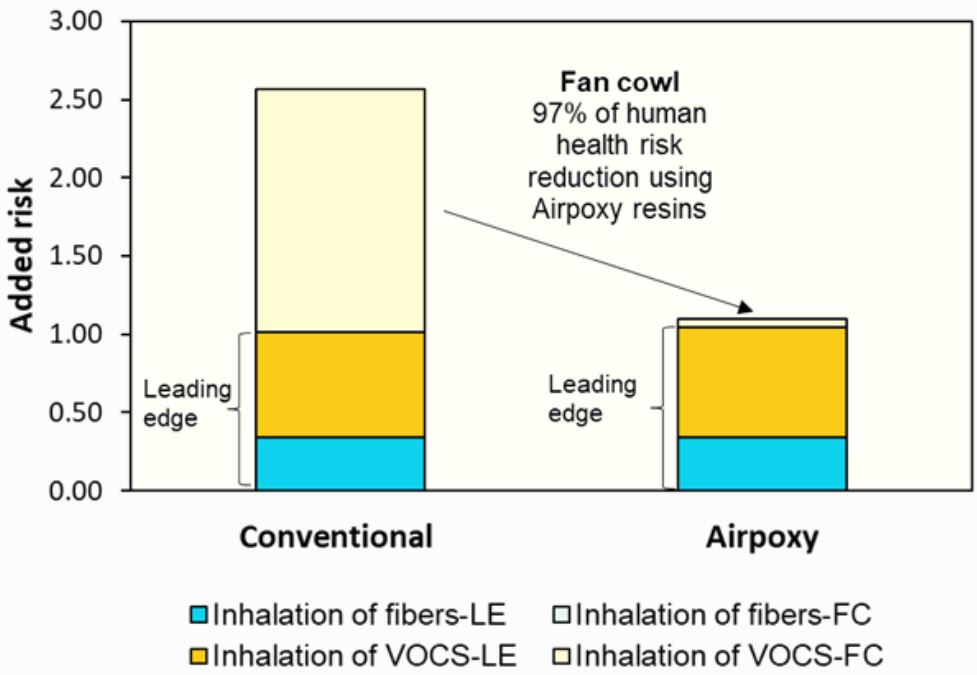


**Top row:** Leading edge SQRTM skin with cocured 3R film (left - photo credit: SONACA) and thermoformed 3R/CF half web (right - photo credit: EIRE Composites) **Bottom row:** Fan cowl RTM 3R/CF skin and transverse stiffener (left - photo credit: IDEC) and thermoformed 3R/CF longitudinal stiffener (right - photo credit: EIRE Composites)

# Environmental, economic and human health risk assessment

Preliminary HHRA calculations comparing the conventional and AIRPOXY technologies show that the new developed 3R resins are less toxic than the ones employed before (epoxy resin). Consequently, the human health risks for the workers that are in contact with these materials are lower in Airpoxy scenarios than in the conventional ones. These gains are being start to be demonstrated by the selected LCA & LCC scenarios deployed, which will be confirmed in upcoming stages of the project, once developments will be finally ready prior to project's end.



# Dissemination and exploitation

On 3 September 2021, a session dedicated to AIRPOXY was organised within the 11th EASN Virtual Conference on Innovation in Aviation and Space to the Satisfaction of European Citizens.

Within the dedicated session, AIRPOXY partners delivered the following presentations:

• AIRPOXY: Thermoformable, repairable and bondable smart epoxy-based composites for aero structures (Cidetec)
• Design of high-performance 3R vitrimers and 3R adhesives for aerospace industry: development, applications, and future trends (Cidetec)
• Bonding strategies for dynamic 3R-resin with functionalized composites surfaces made by the SQRTM process (Coexpair)
• Development of thermoforming technologies for carbon fibre reinforced vitrimer polymers (Leibniz-Institut für Verbundwerkstoffe)
• Knockdown effect assessment between conventional & 3R composites and their repair efficiency via mechanical and non-destructive evaluation (University of Ioannina)

Another highlight of the past year was the feature published by *CompositesWorld Magazine* on the work accomplished by AIRPOXY. The article, entitled "Reprocessable, repairable and recyclable epoxy resins for composites" can be found in the June 2021 issue or via this direct link.

## Standardisation, certification, business plan and commercial roadmap

As part of its standardisation activities, AIRPOXY organises a following CEN Workshop entitled 'Test method for the evaluation of the adhesive properties of fibre reinforced polymer composite joints'. It aims to develop a CEN Workshop Agreement that includes a test method for the evaluation of the adhesive properties of fibre reinforced polymer composite joints. A virtual kick-off meeting targeted at the global composites market was scheduled for 4 October 2021. More information about the draft project can be found here.

To prepare future industrial implementation of project results, Cidetec and ÉireComposites are, respectively, developing certification and commercial road maps with input from all partners. Extensive market research was carried out to create a business plan for commercialisation of the 3R resin in aerospace, as well as a strategic road map for the project, which specifies the commercial value of the AIRPOXY project as well as a path to value for each of the consortium partners. A SWOT analysis was also carried out and helped to identify that there are significant opportunities for growth using 3R resin technologies.

Our project was also presented at a series of events attended by project partners from September 2020 to September 2021:

**September 2020**

- SAMPE Europe: New 3R Bonding Technology for Reparable, Recyclable and Reprocessable Aerospace Composite Materials. AIRPOXY was represented by Cidetec.

**March 2021**

- Online symposium of the Advanced Manufacturing Technology Institute of Kanazawa University: Composite Manufacturing - New Developments and Trends in Europe. AIRPOXY was represented by Leibniz-Institut für Verbundwerkstoffe.
- Webinar series by the Spanish Association of Composites Materials (AEMAC): Composites 3R - Reparabilidad, Reciclabilidad y Reprocesabilidad. AIRPOXY was represented by Cidetec.
- JEC Connect: AIRPOXY: Thermoformable, repairable and bondable smart epoxy based composites for aero structures. AIRPOXY was represented by Cidetec and ALTAIR.

**June 2021**

- Expert*innen-Tage Verbundwerkstoffe: AIRPOXY – Challenges in Thermoforming of 3R-Vitrimer Based CFRPC. AIRPOXY was represented by Leibniz-Institut für Verbundwerkstoffe.
- 6th International Conference of Engineering Against Failure: Knockdown effect assessment between conventional & 3R composites and their repair efficiency & Repair assessment of 3R composites using various NDE techniques and development of online SHM technologies. AIRPOXY was represented by University of Ioannina.
- Journée Nationale des Composites 22. AIRPOXY was represented by Altair.
- Composites and Sustainability Forum: Three Technologies for Sustainable Composites. AIRPOXY was represented by ÉireComposites.

**September 2021**

- EUROMAT21: Flat Laminate Manufacturing of CF Reinforced 3R-Vitrimer Composites. AIRPOXY was represented by Leibniz-Institut für Verbundwerkstoffe.