3.1 Publishable summary

Project details

Project Title	Novel Aeronautical Multifunctional composite structures with bulk electrical conductivity and self-sensing capabilities
Project Logo	**Coordinator's details**
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Project Summary

The aeronautic industry tends to consider new approaches for aircraft development and manufacture due to ew requirements and ecological policies for more environmentally friendly aircraft. Structures like fuselage or wings appear to be strategic components to be manufactured in lightweight non-metallic composite materials for reducing weight, although new questions regarding electrical conductivity have arisen such as lightning strike protection, static discharge, electrical bonding and grounding, interference shielding and current return through the structure. Moreover, due to the fact that no standards for the electrical characterisation on composite materials are available, it is impossible to have a comparative evaluation of the electrical conductivity level of composite materials.

These functions can be met by the use of arising enabling technologies, such as the emerging family of nanocomposites, which indeed combine mechanical properties, electrical and thermal conductivity, with the potential for increased integration of functions (e.g. sensing, electromagnetic, electrical conductivity , etc) in structural components.

It is clear that there is a need to provide advanced concepts and technologies for increased and optimised use of light-weight composite smart materials. With that idea in mind, the ELECTRICAL project aims at the development of novel multifunctional composite structures with bulk electrical conductivity and self-sensing capabilities for rapid non destructive quality assessment.

Differently from other current ongoing projects, where surface conductivity is the main issue for other functionalities, the main technological challenge for ELECTRICAL is to increase electrical conductivity through-the-thickness of aeronautical CFRP laminates allowing the consideration of CFRP bulk conductivity in aircraft design that will lead to new aircraft architecture concepts with further weight savings and performance increases.

Therefore, ELECTRICAL aims to allow the transition from improved nanoreinforced resins to the exploitation of their enhanced electrical and mechanical properties in full laminates manufactured by automated processes. Therefore, the intention is to develop several strategies for introducing electrically conductive nanofillers into CFRP laminates, establishing the use of bulk doped resin as a baseline for investigation, but developing new engineered nanomaterial based structures that would overcome problems of filtration and re-agglomeration.

Project duration

From 01 October 2010 to 31 May 2014

Project objectives

The main objective of ELECTRICAL is the development of novel multifunctional composite structures with bulk electrical conductivity and self-sensing capabilities for rapid non destructive quality assessment.

The project will exploit properly the excellent properties of CNTs as polymeric resin doping for the development of novel multifunctional composite structures with bulk electrical conductivity and self-sensing capabilities. For that, different lines of work will be approached:

Firstly, this project will investigate and develop alternative emerging methods to manufacture nanoreinforced carbon based composites compatible with current industrial manufacturing processes of composites

Secondly, multifunctionallity concept will be approached, which will consist of the integration of three main functionalities

ELECTRICAL incorporates the following scientific and technical objectives:

a) Improvement of bulk electrical conductivity of aeronautical composite structures to meet requirements regarding static discharge, electrical bonding and grounding, interference shielding and current return through the structure. The technical approach will be based on the conductive properties of carbon based nanoreinforcements when integrated into the laminates.
   At the same time, a global electrical conductivity test method will be defined and set-up in order to have a common understanding: Standardisation of electrical measurement and assessment procedures.

b) Monitoring and optimisation of CFRP curing process by Dielectric Mapping. Taking advantage of the electrical conductivity of CNTs, the dielectric sensor system mounted in the mould will perform non invasive measurements of the electrical properties of the material in the sensor´s vicinity for material-state monitoring (degree of cure, Tg), resin flow in moulds (arrival time, flow speed and direction) and end-of-cure detection.

c) Taking advantage of the piezoresistive behaviour of CNTs, development of innovative CFRP structures with distributed or localised self-sensing capabilities for quality assurance of final component (delaminations, inclusions, etc) by Electrical Resistance Tomography (ERT)
d) Development of state of the art fabrication technologies to convert nanofillers (CNTs and others) into engineered multifunctional preforms, prepregs, buckypapers, etc.., for further use in CFRP structures. CNTs bulk doped resins are also to be considered as the main base-line for investigation in the present project. Synergistic effects of using bulk doped resins and new developed engineered structures will also be under investigation.
e) Manufacture, characterisation and testing CFRP based materials with such multifunctional engineered nanostructures and bulk doped resins. The most broadly used liquid moulding technologies will be considered, although autoclave curing and associated prepreg development will also be considered as the base line.
f) Manufacture and testing of representative panels/prototypes for proof-of-concept of the materials and technologies developed.
g) Health, Environment and Safety issues derived from CNT handling will be specially considered in the project. Partners will be trained in the processing of nanomaterials in laboratory and industrial environment, which is a major issue in current development of these technologies.

The project for the first time allowed the transition from improved nanoreinforced resins to the exploitation of their enhanced electrical and mechanical properties in full laminates manufactured by automated process.

During the project, different strategies to incorporate carbon nanotubes in composite laminate using the common manufacturing process (infusion, RTM and/or prepreg) have been successfully investigated. The strategies supposed the study and understanding of the mechanisms that govern the behaviour of the doped resin during the infusion process, the development of dry engineered structures such as buckypapers to be implemented in infusion and prepreg, the exploitation of the thermoplastic interlayers commonly used as toughening materials as potential carbon nanotubes carriers to be implemented in infusion and prepreg and the development of specific treatments for commercial prepregs with carbon nanotubes. The three technologies further matured up to the end of the project: buckypapers, doped veils and CNT treated prepreg have been well adapted to the common composite manufacturing routes. The first goal of the project is that the technologies can be implemented in current manufacturing processes for composite laminates. The objective of the enhancement of the through the thickness electrical properties has been partly reached as the technologies allow to enhance the electrical conductivity in the z direction but none of them reach the conductivity values initially set in the project. With respect to lightning strike performance the technologies do not pass the minimum requirements as the surface impacted is damaged. However, the presence of the technologies diminishes on the lightening impacted surface and reduces lightly the total delaminated area the damage when compared to the panel with no Cu mesh on it. Therefore, the combination of the technologies with a lighter Cu mesh could be the basis for future activities.

The fact that the CNT doped composite systems did not perform as well as existing solutions for the aggressive lightning strike tests, does not exclude them from use in other less aggressive electrical and thermo-electrical applications within the aircraft structure. These uses might include applications for edge glow, anti-icing and de-icing in which the inherent performance of the current solutions are more closely suited to the requirements of these systems. Further development and enhancement of doped composite structures, or the use of hybrid solutions, could enable the properties of these composite solutions to approach the requirements needed for LST protection.