ACRONYM
Title

State of the art – Background

The use of epoxy matrix doped with carbon nanotubes (CNT) on composite material increases the electrical conductivity that could lead to the removal of cooper lightning protection mesh of advanced composite airframe structures. Also, the CNT addition should induce an increase of the final composite component's toughness. This would lead to major weight and cost savings for aircraft OEM's.

State of Art in application of CNT to airframe structures was limited to laboratory level investigation. Such investigations with different combination of CNT and concetrations being integrated in epoxy resins, have demonstrated the promising characteristics of this technology.

No full-scale application on airframe structure was done before Bulcanatu, being one of the main issues the development of a CNT doped resin with good enough electrical conductivity properties that was suitable for being produced at large scale, to allow industrialization.

The incorporation of CNTs into a polymer matrix along with long fiber reinforcements for producing hybrid composites, have recently attracted significant attention. Due to its comparatively low manufacturing costs, the LRI is ideal for impregnating reinforcement fabrics with CNTs resin mixture, obtaining high performance composite parts that can lead to increase of fuel efficiency and lower costs of future CNT composite manufactured aircraft components.

Objectives

BULCANATU project focuses on developing feasible techniques for advanced and cost effective composite manufacturing technologies of aviation structures. The main objectives are the development of a new epoxy resin doped with carbon nanotubes along with the definition of the methodology and the design and manufacturing of the necessary associated tools for the production of a composite aircraft structure through resin infusion technique.

The resulting properties of the doped resin were expected to provide enough conductivity to allow removal of grounding network installed on composite structures of aircraft, and even lightning strike protection.

The expected development in CNT doped resin and manufacturing techniques shall allow produciing full-scale aircraft demonstrators. The selected part is a Rear Pressure Bulkhead for a single-aisle size aircraft.

Description of work

The main challenges of this project are the efficient dispersion and stability of the CNT into the epoxy resin, manufacturing of high performance composite parts under "out of autoclave" conditions at greater viscosities of doped resin and overcoming the expected filtration phenomena within the infusion process.

Project was developed as follows:

WP1: Manufacturing methodology of CNT doped resin dispersion

Whose objective was the investigation on the most suitable combination of resin, CNT types and concentration.

WP2: Manufacturing Methodology to produce an aircraft quality composite part

This WP developed on manufacturing techniques for infusion of CNT resins, as well as characterization of the resulting composite material.

WP3: Definition of tooling configuration
This WP was devoted to the design of the tooling required for producing the full-scale demonstrators. It included simulations on the infusion process with outstanding results.

WP4: Manufacturing of Necessary Tooling
All tooling was manufactured applying composite materials and techniques for tooling development.

WP5: Quality Control on Necessary Tooling
All tooling produced was inspected and measured according to the company's standards.
Interferometer Distance Accuracy ±0.

WP6: Production of Bulkhead Demonstrators
Two full-scale aircraft Rear Pressure Bulkhead with 8 stringers co-infused were manufactured using CNT doped resin.

One of the demonstrators was used to extract coupons for testing, whereas the other for exhibition purposes.

WP7: Non-Destructive Testing
A number of NDT were performed. The quality of final part was determined, analysing the extracted coupons. The main goal of the inspection was the analysis of filtering effect, studying samples located at different distances from the LRI resin inlets. In addition, non-cured resin was collected from the resin inlet and outlet to confirm the presence of nanotubes in the whole multiscale material.

On the other hand, the density of the multiscale composite was also measured to analyse the quality of the material of the manufactured bulkhead. It allowed to study the presence of porosity of the final multiscale composite

WP8: Quality Control of Demonstrators
The quality control steps according to internal procedures submitted to EN9100/ISO9001 quality system include:

- Inspection of carbon tools prior to LRI manufacture process.
- Airtightness check of tools prior to lamination.
- Fibre Placement process traceability. Cure and Post-cure Process traceability
- Inspection of manufactured LRI parts for imperfection and non-conform zones
- Metrology Inspection of parts for approval. It is going to be used the Leica Laser Tracker for this purpose, available at TRC facilities.

Results

The topic's target was to evaluate important parameters, such as the Carbon Nanotubes (CNTs) content, mixing procedure, duration, type of epoxy and CNTs functionalization, for the Liquid Resin Infusion process (LRI) processes and develop techniques to allow manufacturing. After that, a demonstrator was manufactured using the researched manufacturing techniques.

In this context, Bulcanatu main resuts are:
1) a CNT resin was developed in a process suitable for scalation at aircraft primary structure quantity needs.
2) a full-scale demonstrator (under limited technical conditions) could be successfully infused with such resin.
3) under the limited conditions, this first attempt resulted in part conductivity levels in the range of conductivity requirements for electrical bonding.

a) Timeline & main milestones

Project main milestones were:
D1: determination of the most appropriate CNT doped resin.
D2: development of infusion techniques and characterization of resulting hybrid composites
D3: Tooling design freeze

D4: Tooling produced
D5: Tooling measured and inspected
D6: Manufacturing of full-scale demonstrators
D7: NDT on demonstrators
D8: Demonstrators measured and inspected

b) Environmental benefits

Bulcanatu project is a successful first step towards eliminating the need of electrical bonding networks (metallic plates, ribbons, etc.) on aircraft structures. Achieving this final goal would imply:
a) Major cost savings at assembly (thousands of systems installation ours per aircraft and related grounding networks' materials)
b) Removing electrical bonding networks would imply major weight reduction opportunity for aircraft (the project partners do not have relevant information on this context). Moreover, this technology could become a major driver for further weight reduction in aircraft composite structures, thus strongly contibuting to suitanable aviation.
c) Less relevant, from a design standpoint, the activities for designing electrical bonding networks would not be needed.

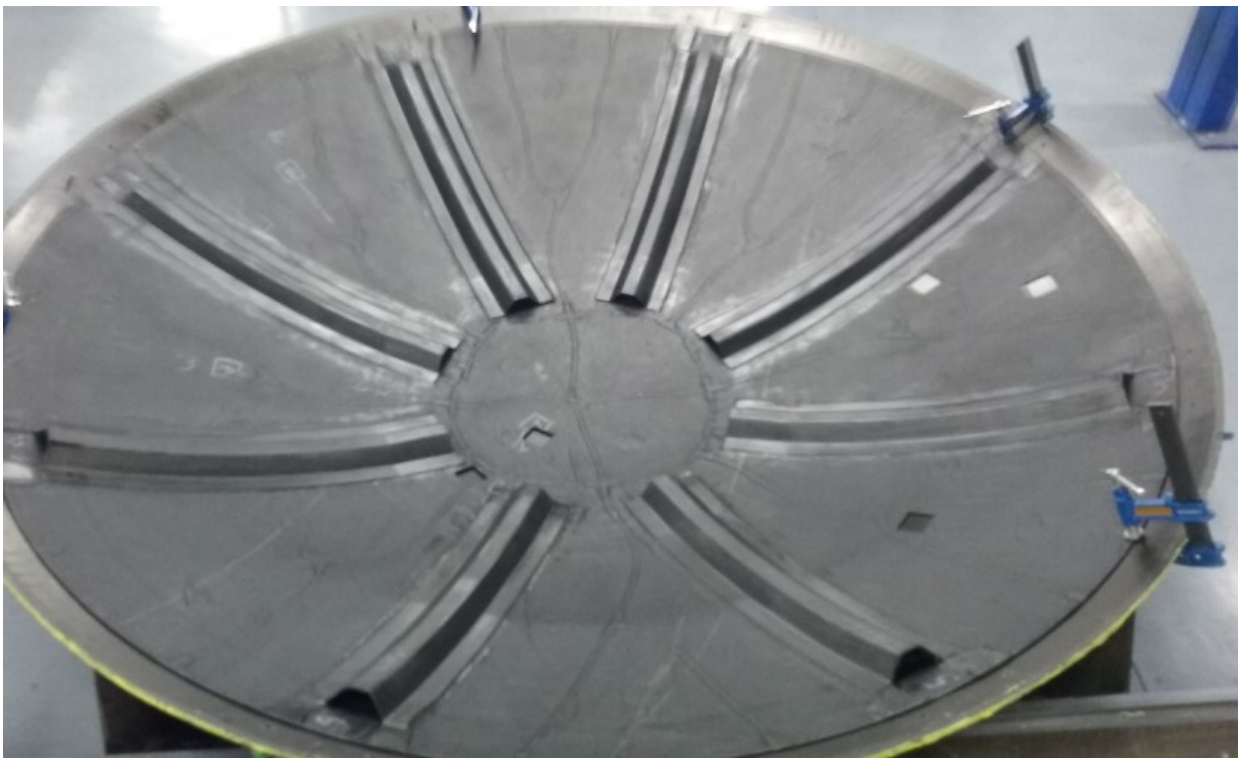
c) Maturity of works performed

In summary, the infusion process has demonstrated the ability to produce a good part from an impregnation and curing points of view for an Out of Autoclave process. This would imply TRL6 maturity level as the following topics shall be addressed in the future, as way forward:

- Continuing the works on producing doped resin at larger volumes to support future serial production.
- To continue on the investigations about the infusion process to reach 5 S/m of conductivity in order to fulfil the most restrictive requirements for electrical bonding applications. Increase of concentration of nanotubes is needed, and in parallel an infusion process suitable for infusing a denser resin has to be developed.
- To investigate in mould concepts that prevents trapping of infusion elements under stringers and caul plates.
- To investigate in reusable bags for infusion in order to shorten production time and reduce risk of manufacturing mistakes.

Picture, Illustration

Pictures of the full-scale demonstrator.



Project Summary

Acronym: BULCANATU

Name of proposal: Development of CNT doped reinforced aircraft composite parts and associated tooling, using the Liquid Resin Infusion method.

Technical domain: Composites, CNT doped resins, infusion

Involved ITD: GRA

Grant Agreement: 325967

Instrument: Clean Sky JU

Total Cost: 181.136,05€

Clean Sky contribution: 85.921,62€

Call: CS-2012-1

Starting date: 01/08/2013

Ending date: 31/03/2016

Duration: 32 months

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