



## Eco Fairs

### Eco-design and manufacturing of thermoplastic structural fairing for helicopters

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July 2011-July 2014

THEME [JTI-CS-2010-5-GRC-06-002]



# CETMA

## works for your innovation goals

*Advanced materials*



*Virtual prototyping,  
modelling and simulation*



*Materials testing*



*Prototypes production*



*Processing technologies*



CETMA centro di progettazione, design tecnologie del materiale  
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CETMA carries out **applied research** activities on materials, processes and methodologies towards the **development of innovative products** for industry and services sectors.



## The Clean Sky programme

**Clean Sky**, a Public Private Partnership between the European Commission and the Aeronautical Industry, **was set up to bring significant step changes regarding the environmental impact of aviation.**

**Clean Sky will speed up technological breakthrough developments and shorten the time to market for new and cleaner solutions** tested on full scale demonstrators, thus contributing significantly to reducing the environmental footprint of aviation (i.e. emissions and noise reduction but also green life cycle) for our future generations



## Final aim of the Eco Fairs project

***Design support, Manufacturing, Joining technology selection, Non Destructive Inspection (NDI), Mechanical characterization and Certification support for the following new Thermoplastic Structural components:***

- Upper Panel Rear Fuselage Demonstrator;
- Sponson Fairing Demonstrator;
- Radome Demonstrator.

**Increasing use of composites for weight reduction in aerospace**



**Out of Autoclave Technologies (high production rates, automation, control)**

**Green processes**



**Thermoplastic composites**



**Recycling**



**Low adhesion properties**



**Limits with the manufacturing of complex shapes**

**Critical issues**

**New Joining techniques for thermoplastics**



- High production rates;
- Automation;
- Control → reliability



## **WP1 (Study of materials, processes, design specifications)**

### **Main results of the WP1:**

- building block approach for the thermoplastic composites;
- Material selection (carbon-PPS composite provided by Tencate);
- Process selection (compression moulding-rubber, assisted compression moulding)

**a robust methodology for the design, material selection and manufacturing of thermoplastic composite components for helicopters was developed!**

## WP2 (Joining technologies selection)

From the results of WP1 activities, it was clear that the main critical points for the development of structural component for aerospace sector with thermoplastic composites were related to:

- The limit of thermoplastic composites for the manufacturing of components with complex shape;
- The need of joining systems for thermoplastic composites with high performances.

Among the other joining techniques, the induction welding of thermoplastic composites was developed and deepened.

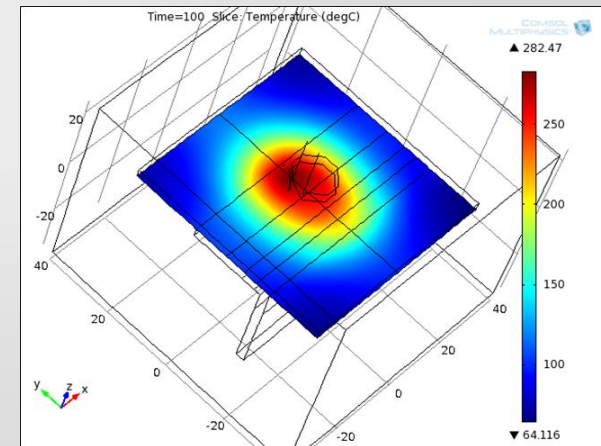
The results of these R&D activities were extremely significant:

“CETMA developed an induction welding procedure that matches the requirements of aeronautic sector”



**Induction welding equipment**  
**Patent pending (TO2013A000367)**

**FEM analysis of the induction welding process**

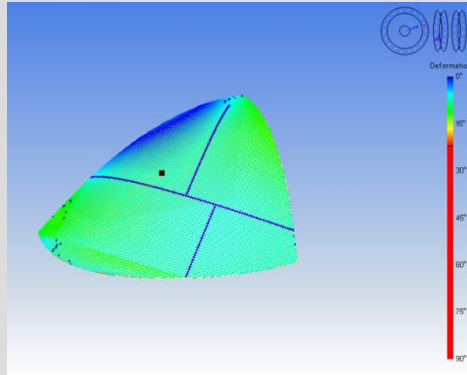




## WP3, WP4 and WP5 (Demonstrators manufacturing)

Upper panel, Sponson Fairing and Radome design and manufacturing were carried out.

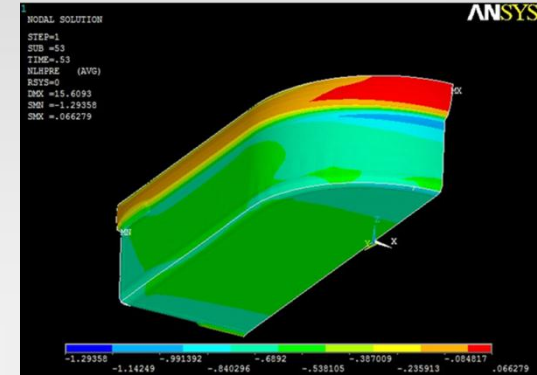
**Draping analysis**



**Design**

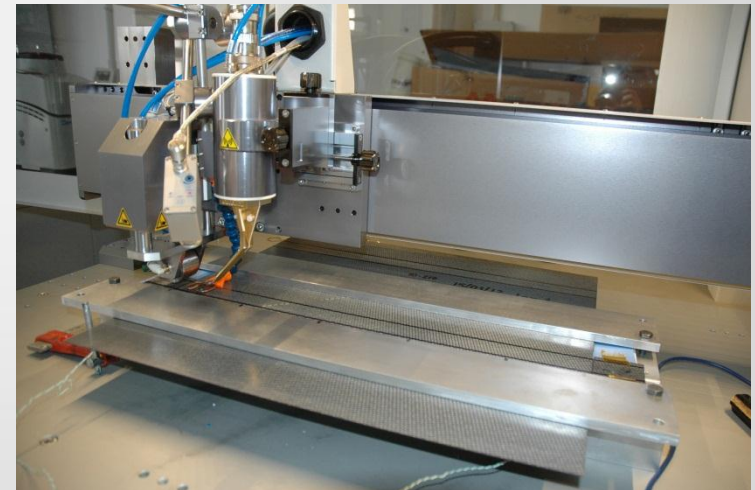


**Process simulation**



**Radome Rubber forming**

**Tooling  
&  
Manufacturing**

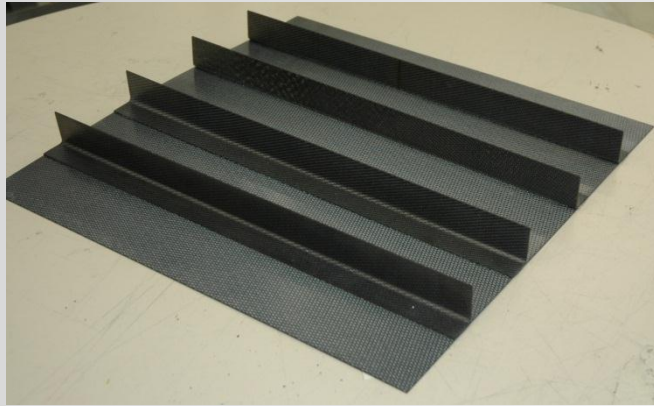


**Upper panel induction welding**



## WP3, WP4 and WP5 (Demonstrators manufacturing)

Upper panel, Sponson Fairing and Radome design and manufacturing were carried out.



**Upper panel**

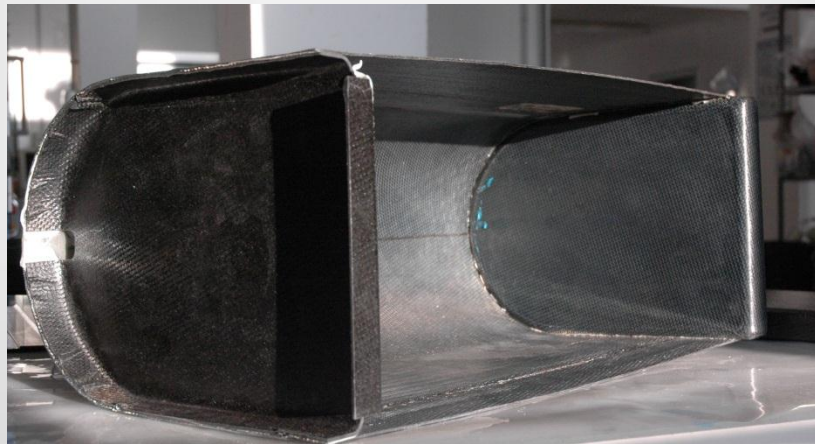


**Prototypes**



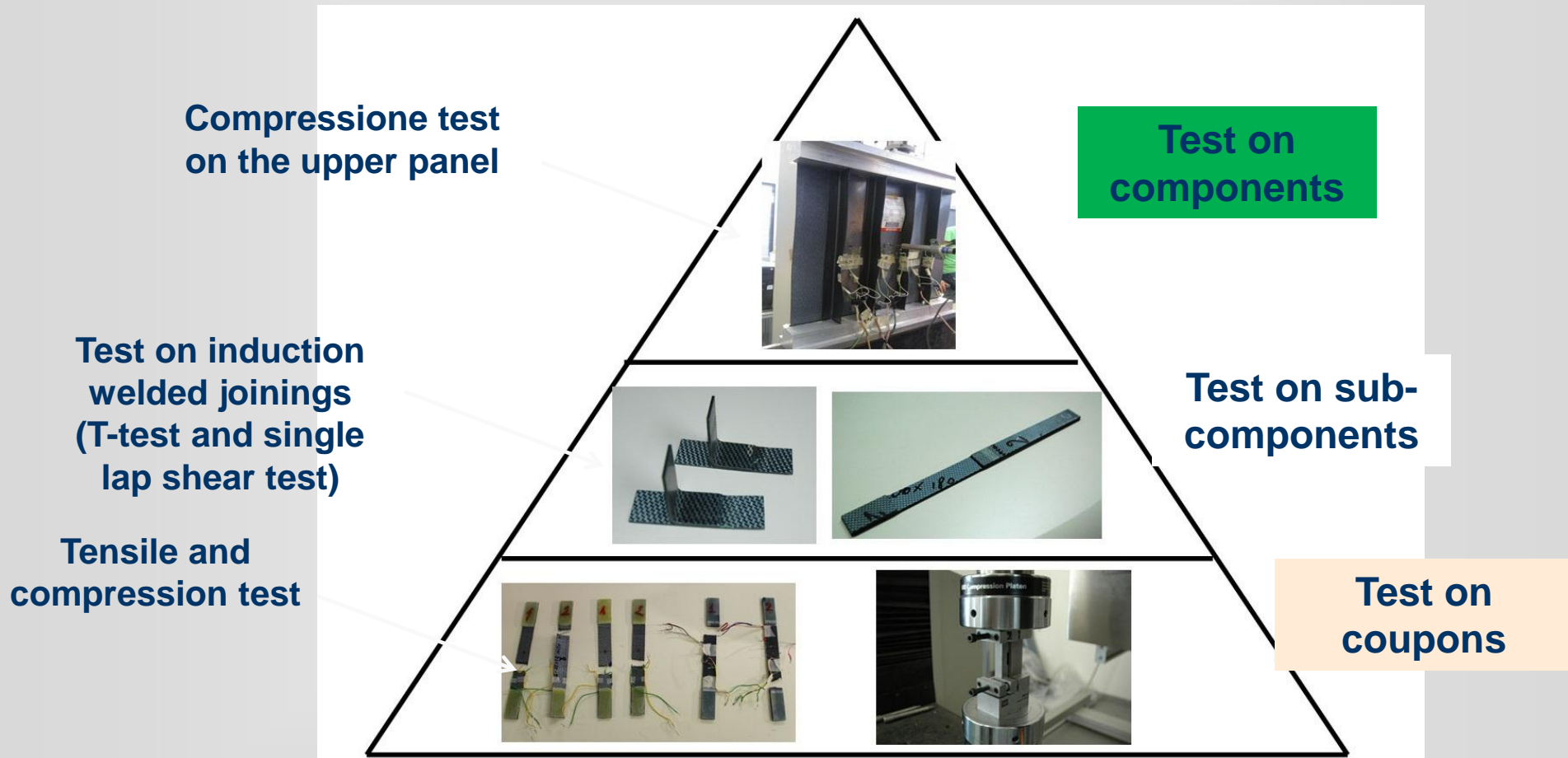
**Radome**

**Sponson  
Fairing**



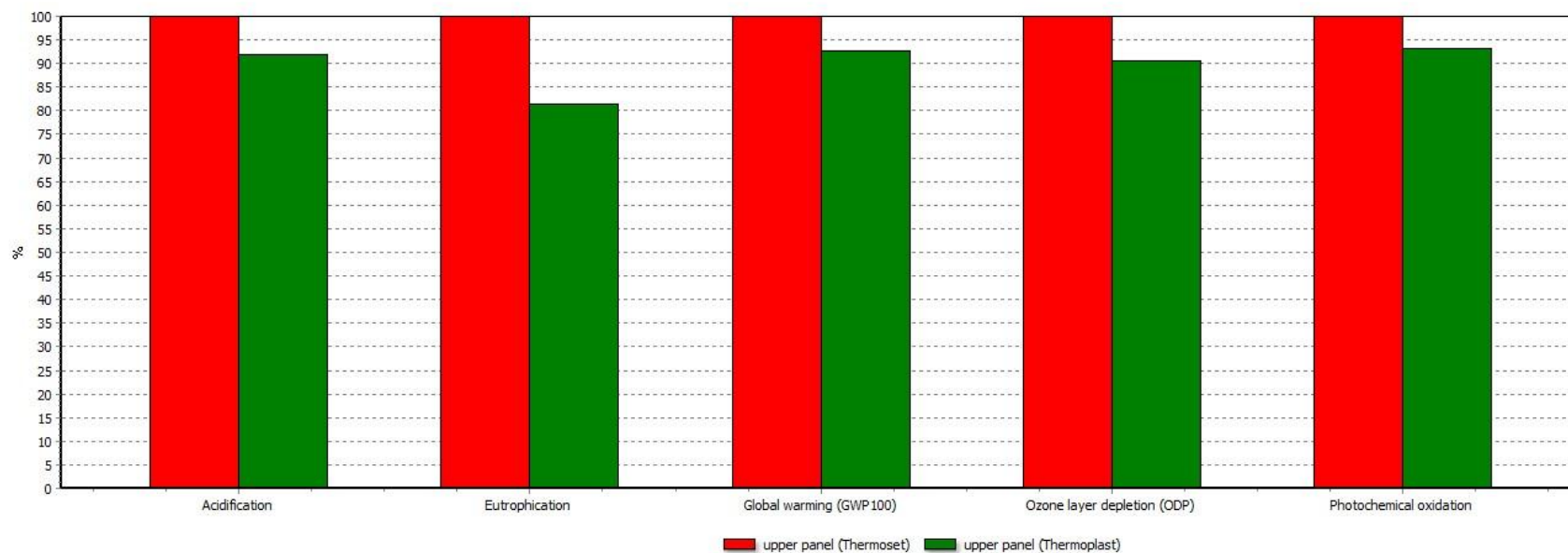
## WP6 and WP7 (Plan for certification and evaluation of demonstrators performances)

The test matrix and NDI plan were defined according to the building block approach.



## WP6 and WP7 (Plan for certification and evaluation of demonstrators performances)

Eco-quotation of the three demonstrators showed how the environmental impact of these thermoplastic components is smaller than for thermoset ones.



Comparing 1 p 'upper panel (Thermoset)' with 1 p 'upper panel (Thermoplast)';  
Method: EPD\_GG V2.04 / West Europe, 1995 / Characterisation

## Summary of the main results of the Eco Fairs project

***Development of a methodology design of complex shapes (sponson fairing, radome) and functional structures (upper panel) with thermoplastic composites.***

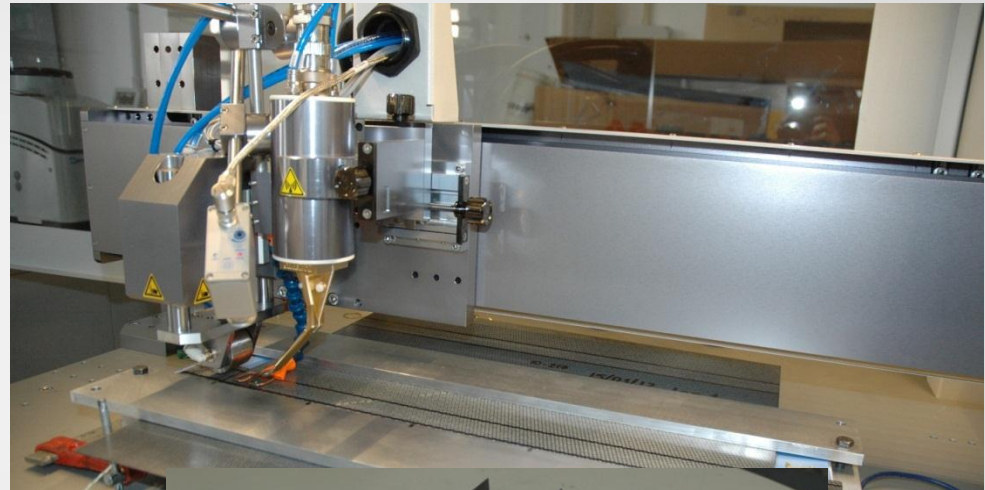
***Manufacturing of TPC demonstrators by means of out-of-autoclave processes***, for the production of cost-effective products.

***Development of quality control procedures and characterization procedures for TPC components.***

***Development of an advanced joining method for TPC parts (induction welding)***, in order to take profit of other technological properties of TPC and to overcome their bad adhesion ability with respect to thermosets.



**A new induction welding machine for continuous welding of thermoplastic composites was developed by CETMA and SINERGO.**



**An innovative method to join  
composites**



**High performances**

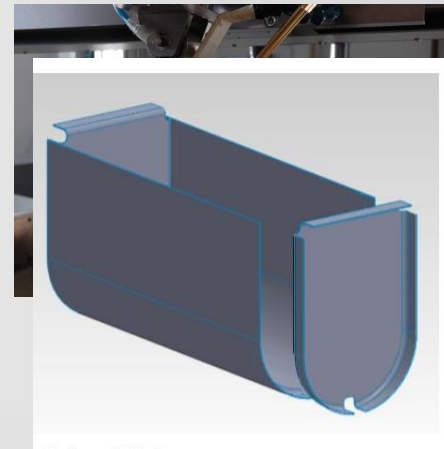
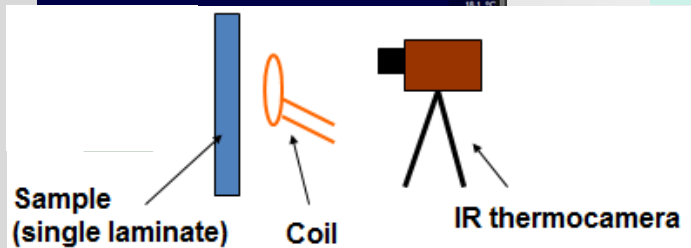
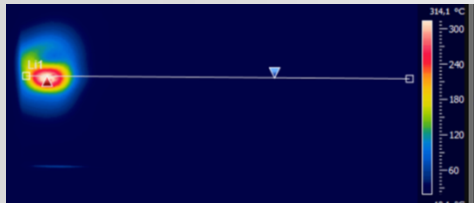
**Reliability**

# Why Induction Welding?

**Low costs**

**Flexibility**

**Easiness of automation**

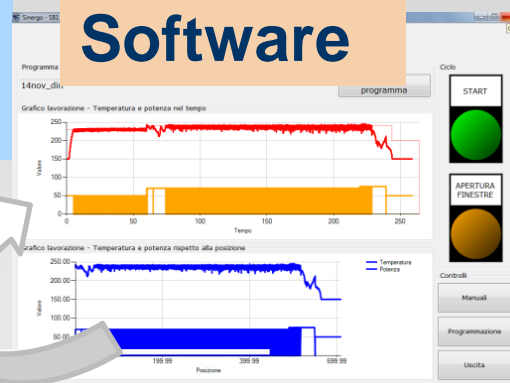
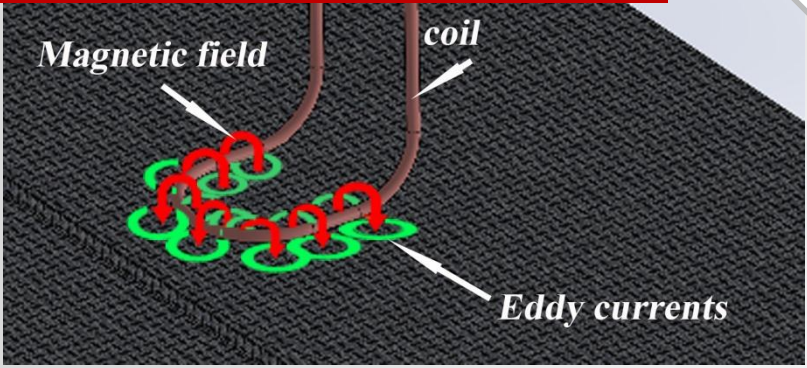




**Overheating of free surface!  
Edge effect!**

**Induction welding phenomenon**

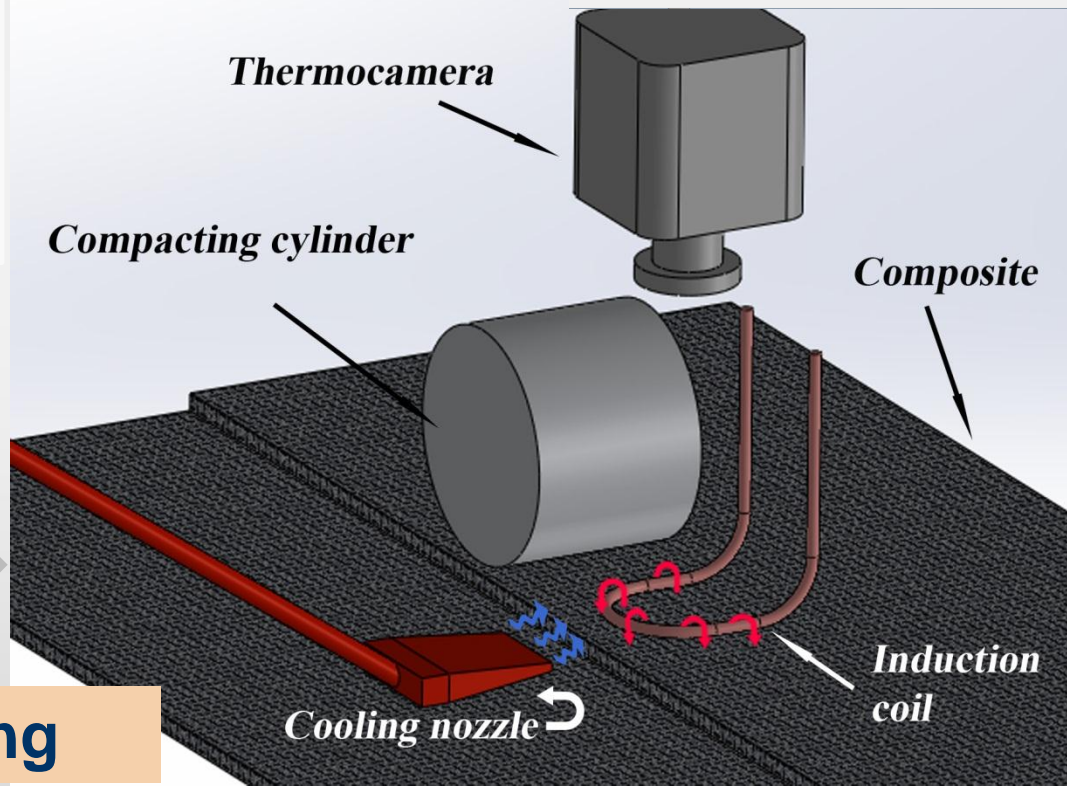
**Software**

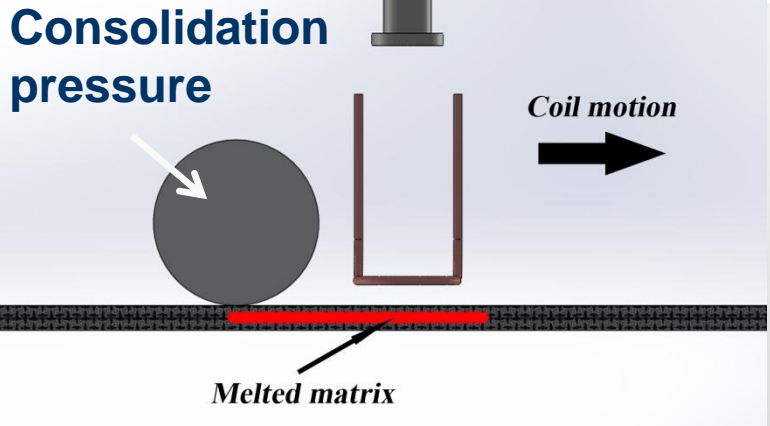
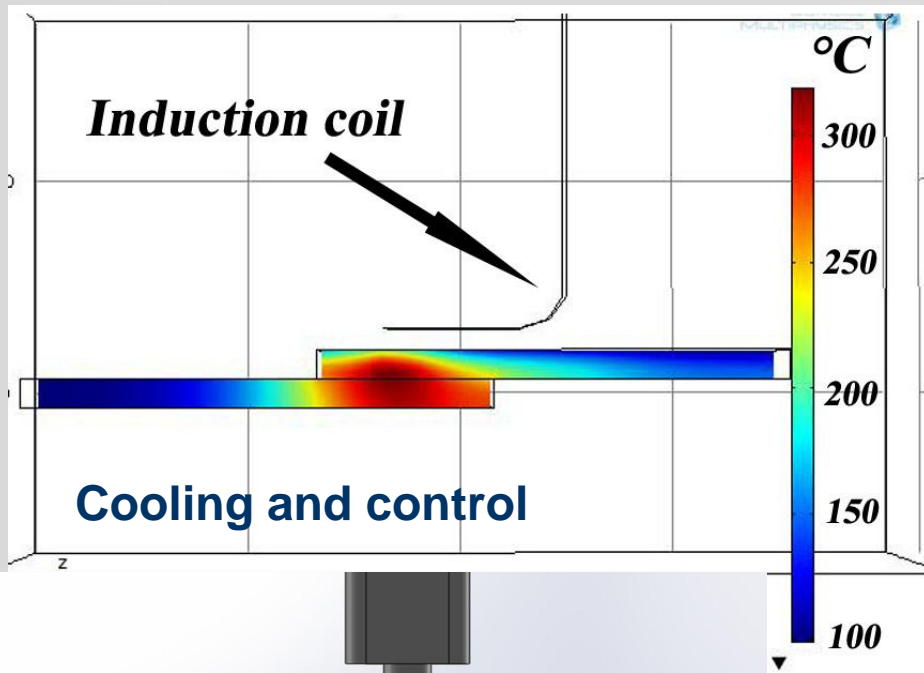


**Cooling+control!**

**CETMA-SINERGO  
Induction welding  
machine**

**Patent pending**



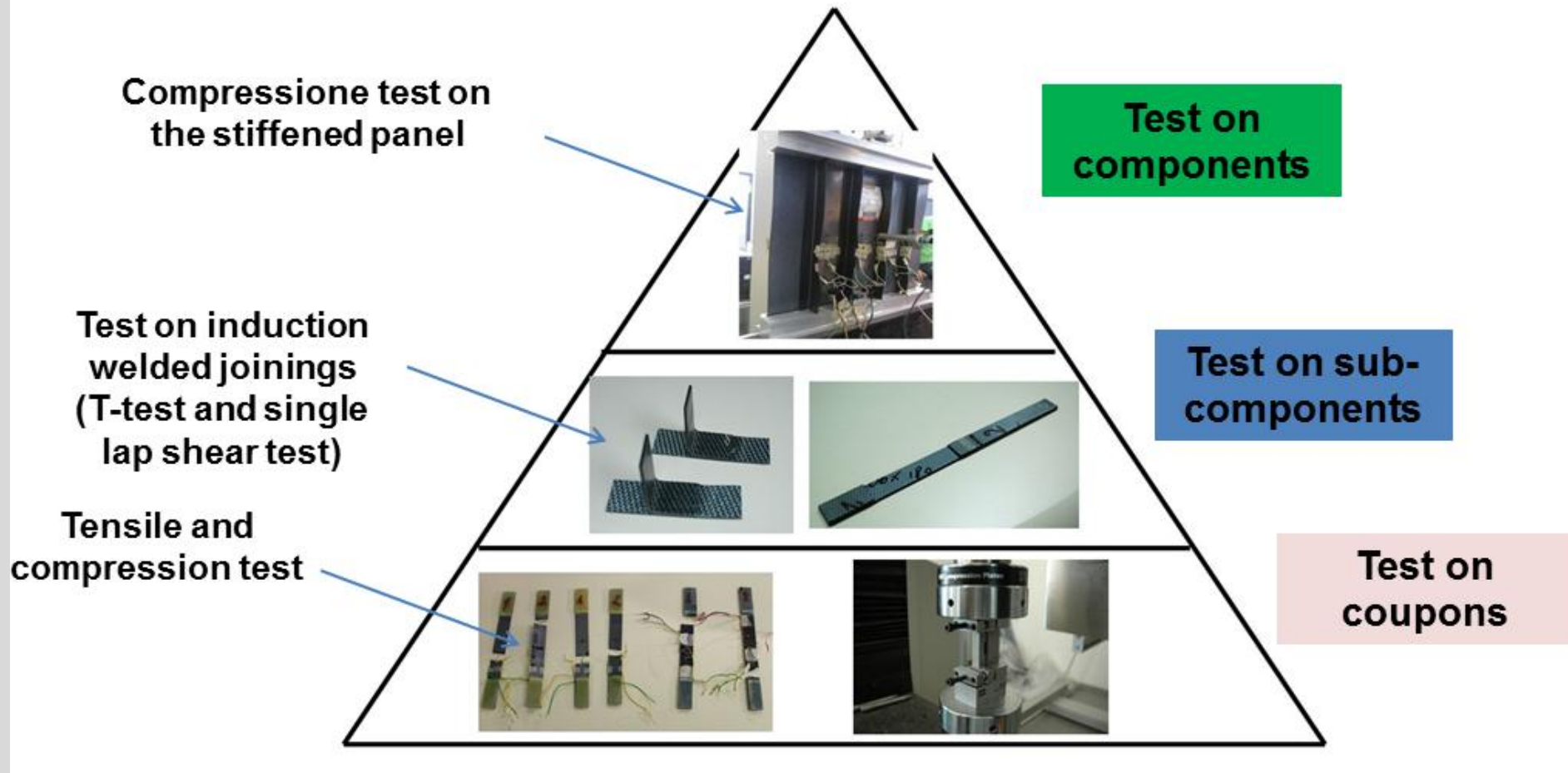


**FEM model → optimization of process parameters**

**Optimal temperature distribution within the material!**

**No edge effect!**

**The building block approach was used to validate the process.**



**Material: CETEX® PPS /carbon provided by TenCate  
(T300 3K 5HS/PPS with double sided Amcor foil)**

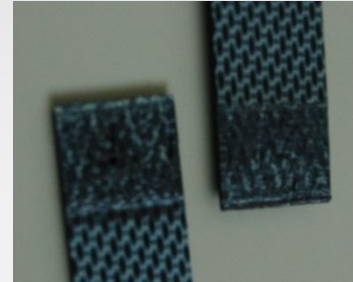
# Test on sub-components

At first mechanical tests were carried out on coupons and sub-component

Single lap shear strength  $\rightarrow 30 \pm 1$  MPa

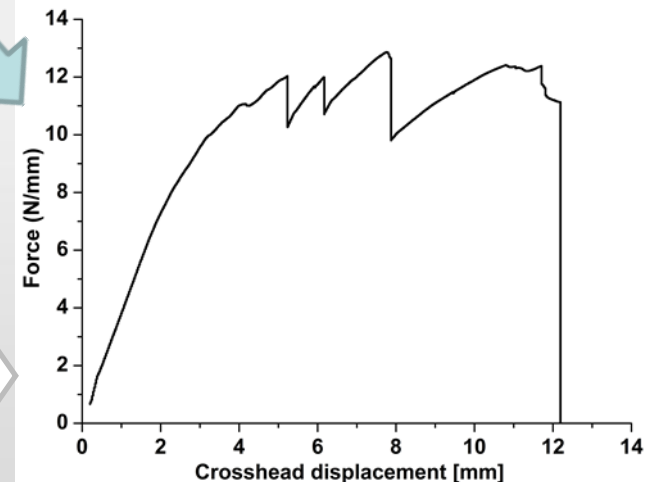
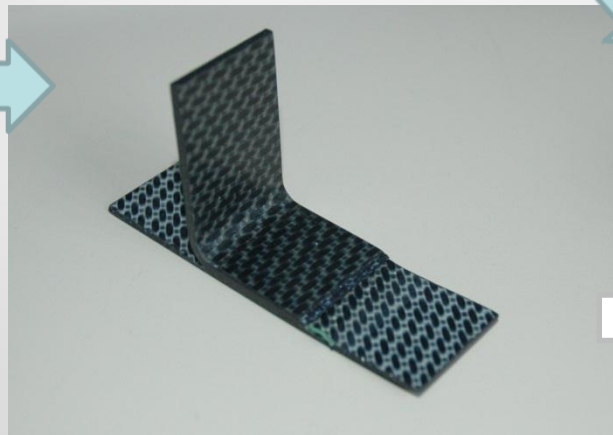
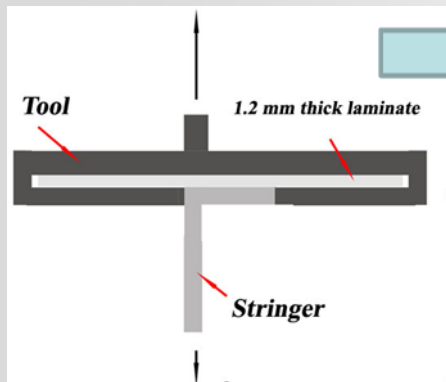


Overlap length 25 mm



Good damage tolerance

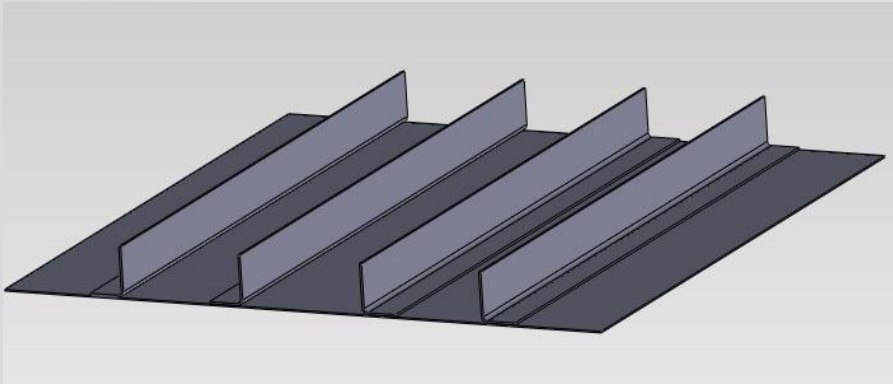
Pull-off strength  $\rightarrow 10 \pm 0.5$  N/mm



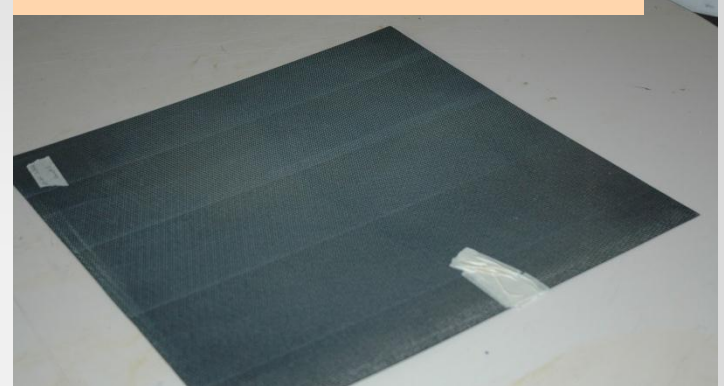


# *Test on component*

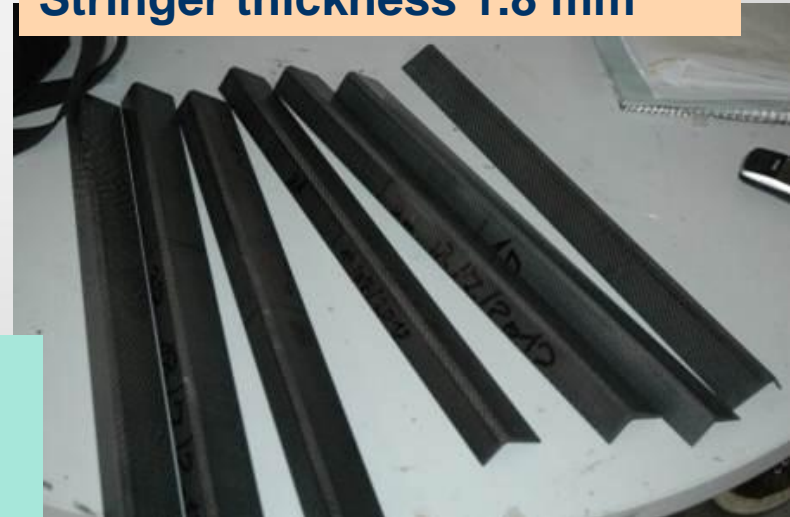
Different stiffened panels were manufactured welding L-stringers on flat panels.



Panel thickness 1.2 mm



Stringer thickness 1.8 mm



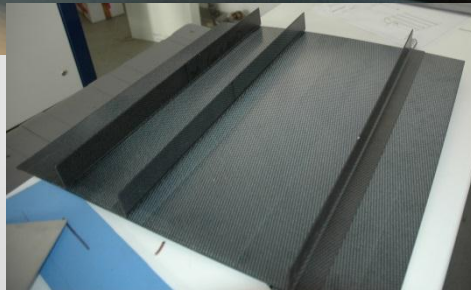
Not-isothermal  
compression  
moulding process



# *Test on component*

Induction welding of the stringers on the flat panel.

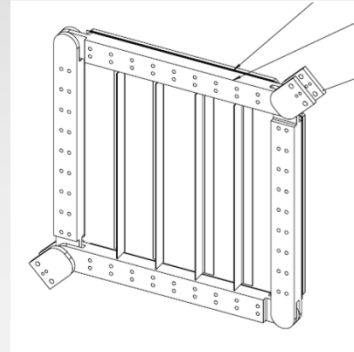
- Welding velocity: 2mm/s
- Max Power: 3.3 kWh
- Max temperature on the free surface: 220 °C;
- Max temperature in the joining interface: 340 °C





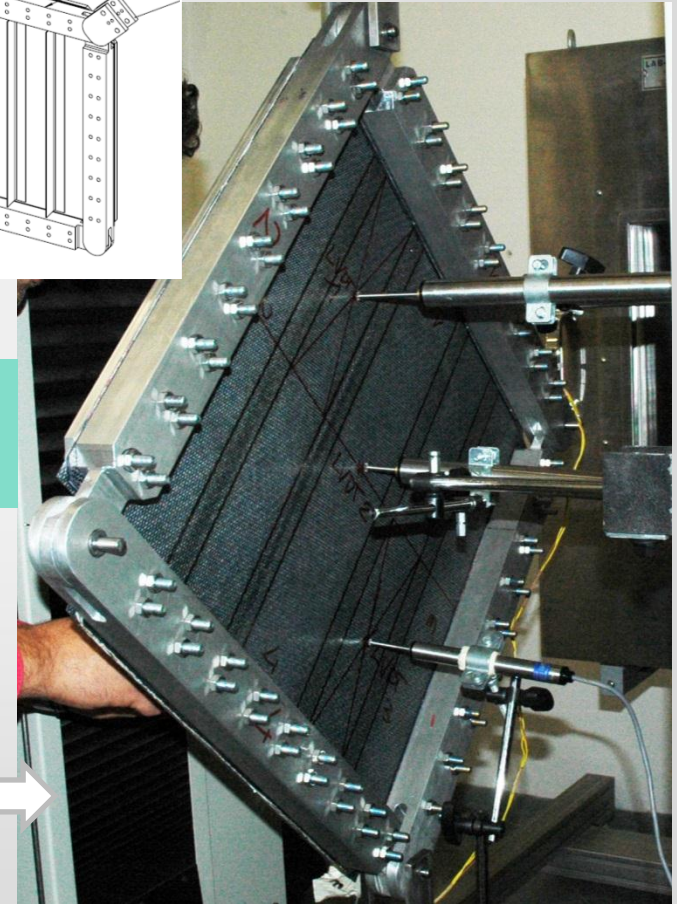
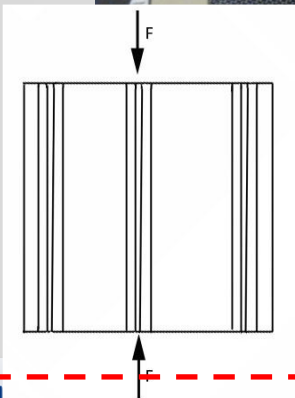
# *Test on component*

Compression and shear tests were carried out on the stiffened panels.



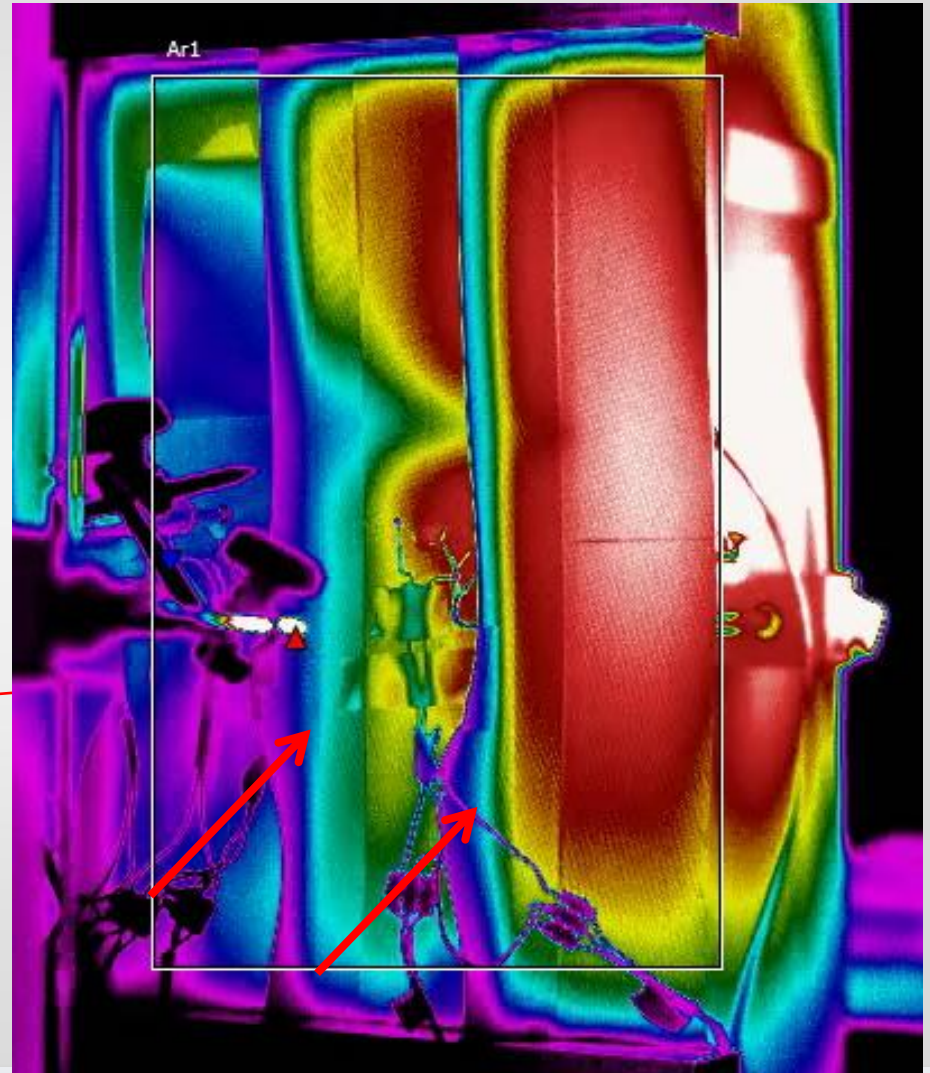
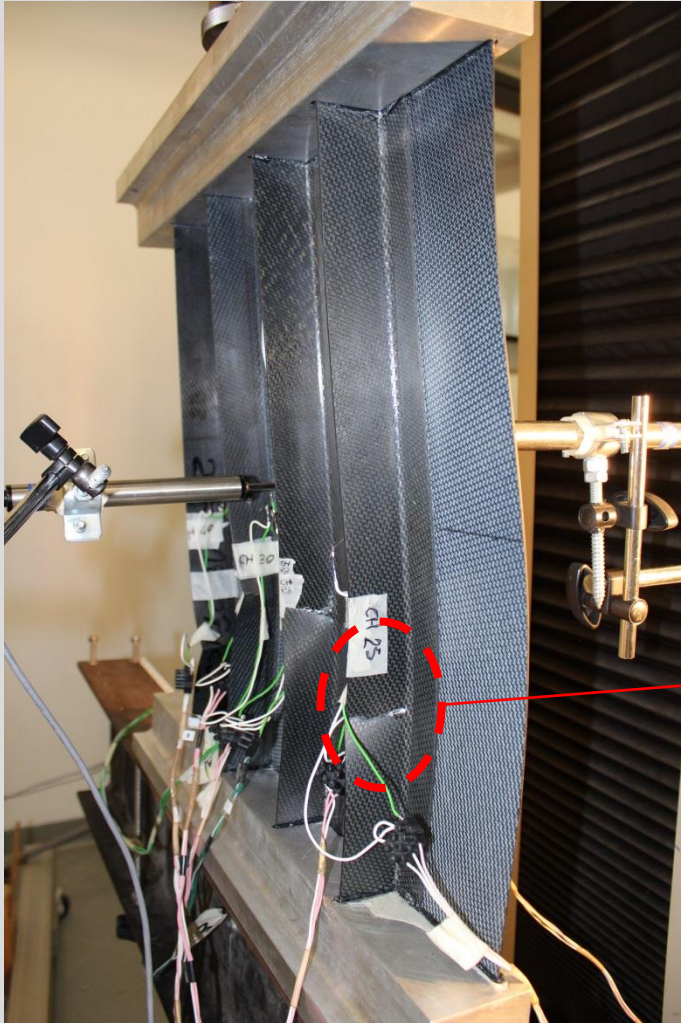
Compression test

Shear test



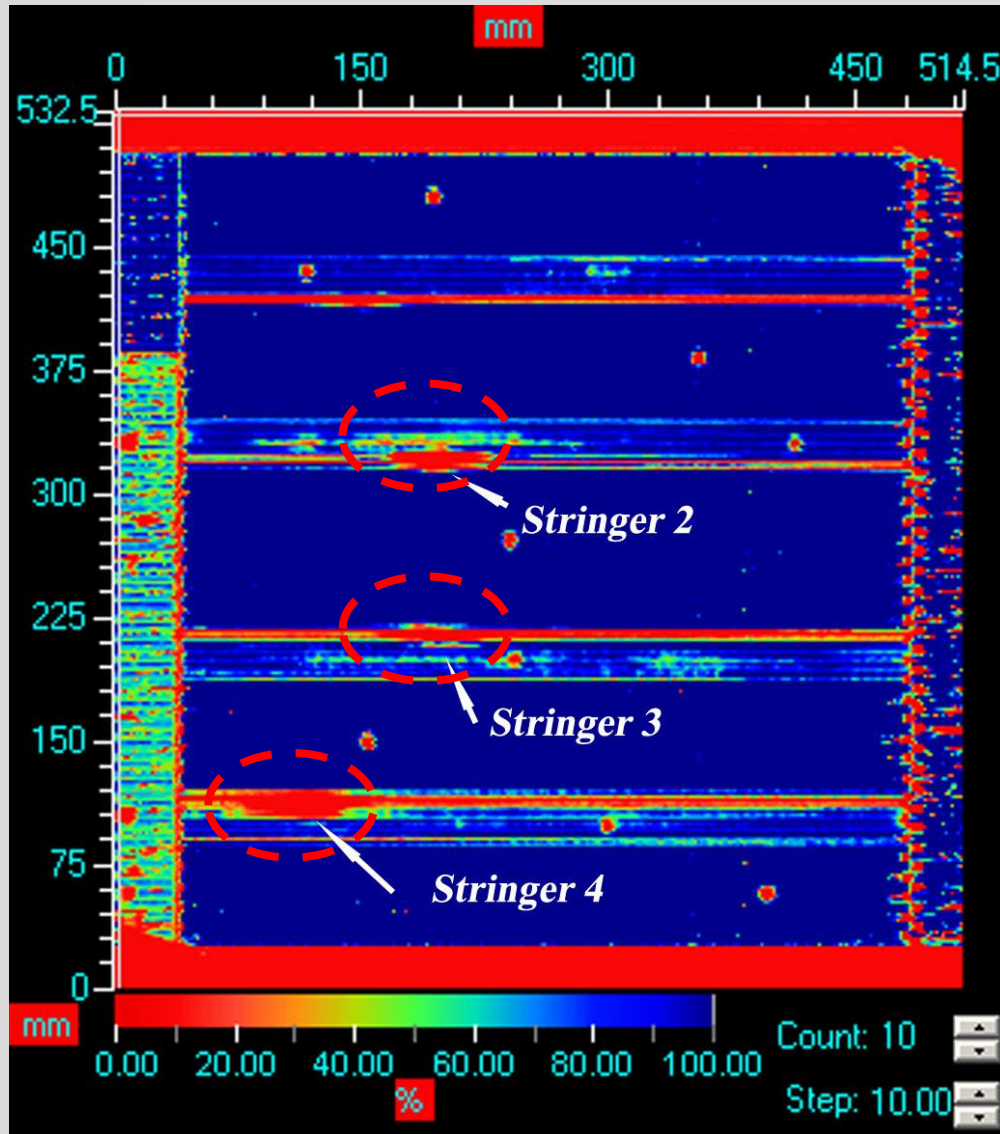
# *Test on component*

During the compression test stringer de-bonding was not observed.





# Test on component



Ultrasonic C-scan analysis on broken panel showed that de-bonding occurred only close to the failure zones of the stringers



## Dissemination\communication\patents

- Submission to scientific congresses of papers discussing of the results of Eco-Fairs project:

S. Pappadà, A. Salomi et al. “Finite Element Simulations to Support Continuous Induction Welding of PPS-Carbon Composites” SEICO 13, 11-13 March 2013 “Paris”.

S. Pappadà, “Finite element simulations to support the development of out-of-autoclave technologies”, Business Improvement by performance simulations in A&D, 11-12 Oct 2012.

Pappadà S., Salomi A. et al., “Development of a New Induction Welding Machine for Thermoplastic Composites in the Aerospace Sector” Italian Association of Aeronautics and Astronautics XXII Conference Napoli, 9-12 September 2013.

S. Pappadà, A. Salomi et al. “Full scale tests on thermoplastic components for aerospace sector” SEICO 14, 10-11 March 2014 “Paris”.

ITTO2013A000367 INDUCTION MACHINE FOR BONDING POLYMERIC MATRIX CONDUCTIVE COMPOSITE MATERIAL AND BONDING METHOD FOR SAID MACHINE

At last it is planned to submit two papers to scientific journals with impact factor in the next year.



Ministero dello Sviluppo  
Economico



Ministero dell'Istruzione,  
dell'Università e della Ricerca



Regione Puglia  
Area Politiche per lo Sviluppo  
Economico, il Lavoro e l'Innovazione



## Bando AIUTI A SOSTEGNO DEI CLUSTER TECNOLOGICI REGIONALI PER L'INNOVAZIONE

Il CETMA supporta le aziende nelle seguenti fasi:

- ☐ Coordinamento tecnico nella preparazione della proposta
- ☐ Individuazione dei partner
- ☐ Supporto per attività tecniche durante il progetto (“ricerca a contratto”)
- ☐ Supporto per attività gestionali durante il progetto

**Per informazioni e condivisione dell'idea progettuale:**

**Ing. Alessandro Marseglia – [alessandro.marseglia@cetma.it](mailto:alessandro.marseglia@cetma.it) - 0831 440408 - 333 2620456**

