Executive summary

The Eco-Fairs project aimed to design and manufacture three structural fairings for helicopters using thermoplastic composite materials and with reduced environmental impact:

- Upper panel Rear Fuselage demonstrator;
- Sponson Fairing Demonstrator;
- Radome Demonstrator.

The three demonstrators were designed and produced according the technical specifications with a TRL6 Technology Readiness Level.

A robust methodology to design and manufacture thermoplastic composite structural components for the aerospace sector was defined in the first WPs, and a number of guidelines were collected. Then the materials and process selection was carried out. The analysis of the thermoplastic composites for the aerospace sector led to the identification of CETEX® (provided by TENCATE), a carbon T300 3K 5HS textile with double sided PPS film. The last important issue that was analysed in WP1 was the manufacturing process selection. The main processes to produce thermoplastic composite components were analysed and described. Among these processes, the compression moulding technique was chosen for the demonstrator manufacturing, because this technique allows a robust control process with good performances and high volume rates. The main guidelines of the compression moulding process were found and described and robust numerical and experimental tools were developed to define optimised process parameters. The final result of WP1 was the definition of a robust methodology for the design of the manufacturing process of thermoplastic composites for the aeronautic sector.

The critical issues regarding the manufacturing of components with complex shape makes clear the importance of the joinings for thermoplastic composites. The definition of robust and high performing joining techniques for advanced thermoplastic composites is the key point for the overcoming of this limit. In the first part of WP2 the joining methodologies for thermoplastic composites were analysed. Thermoplastic welding techniques were studied, because of the possibilities to obtain high performances of the joints, and induction welding revealed to be the most well promising technique. This technique uses the eddy currents generated by an alternating electromagnetic field to heat the material and allows very high performances with a robust control of the process. A new induction welding machine for continuous welding of thermoplastic composites was developed. A big effort in terms of numerical and experimental activities was required for the definition of this machine. The quality of the work performed was confirmed by the high values of the mechanical properties of the manufactured joinings.

In WP3, WP4 and WP5 the three demonstrators of the project were designed and manufactured according the guidelines found in the first part of the project.

In the second part of the project the activities related with evaluation of demonstrators performances were carried out. At first the NDI inspections were carried out according to the NDI plan on the three demonstrators. Then the evaluation of the mechanical performances of the demonstrators was carried out according to the building block approach, starting from testing of material coupon up to the full scale tests on the demonstrators. After the evaluation of mechanical performances the eco-quotation of the demonstrators was carried out, thus demonstrating the lower environmental impact for the thermoplastic components in comparison with the thermoset ones.

Due to the importance of induction welding technique technique for the exploitation of thermoplastic composites for the aerospace sector, in the last part of the project the induction welding process was

optimised also for other advanced thermoplastic composites of interest for the aerospace sector, and namely PEEK and PEI composites. The optimised process parameters were found and the experimental activities to find the design allowables for PEEK and PEI carbon composites were carried out.

Project context and main objectives

Composite materials have been utilized more and more in the last decades for aeronautic and aerospace applications. Starting from lightly loaded structures, the applications have been extended to secondary and primary structures, interested by higher critical requirements in terms of laod carrying capacity and structural reliability. Since the first application were delivered thermoset composites have been preferred over thermoplastic ones because different reasons, such as a more spread knowledge and the easiness of process, better performances at higher temperatures, presence of higher number of experimental data on thermoset materials, components and structures used in aerospace and aeronautic applications.

In the last time a big effort to promote the use of glass and carbon reinforced TPCs to substitute traditional thermoset ones in advanced aerospace structures have been pursued by many researcher and technologists, in order to develop proper methodologies for Ecolonomic design and manufacturing and to take advantage of their promising properties in terms of hot/wet mechanical properties, durability, short production cycle and joining efficiency, reduced tooling and production cost. Some examples of applications of TPC large structures have been developed in the last time, such as the welded wing fixed leading edge operating on A340 and A380, and new primary components are being developed, like the torsion box of the horizontal stabilizer by Fokker aerostructures which is going to get TRL6. Thanks to this big effort, new TPC have been developed using thermoplastic matrixes with higher mechanical and physical performances, both amorphous (like PEI and PES) and semi-crystalline (like PPS and PEEK),in the form of both textiles and unidirectional tapes. Moreover joining technologies have been investigated mainly based on welding processes and sometimes on mechanical fastening.

These examples demonstrate, with different TRLs, that TPC are competing with thermosetting ones, on the basis of their technological and physical advantages: higher toughness, easier recycling, weldability, reparability, infinite shelf life. Despite of these characteristics, thermosetting composites are still largely preferred, mainly due to a certain lack of knowledge and experience of design, manufacturing and validation of thermoplastic structures in aerospace and aeronautic fields, and by not yet fully established procedures for a proper design and exploitation of technological advantages in terms of short cycle and weldability.

All these aspects have lead the interest of the main industrial players of the aerospace and aeronautic sector towards the investigation of such new materials and processes for the development of components for greener aircrafts and rotorcrafts, thus going beyond the apparent difficulties in using TPC.

Following the considerations previously reported, the main objectives of the projects are:

- ***design of complex shapes (sponson fairing, radome) and functional structures (upper panel) with thermoplastic composites***, developing and providing design guidelines and manufacturing procedures for the final demonstrators;
- ***manufacturing of TPC demonstrators by means of out-of-autoclave processes***, for the production of cost-effective products;
- ***development of quality control procedures,*** by means of non destructive inspection able to detect any internal damage or defect due to manufacturing and assembly processes;
- ***select of 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;

- ***development of characterization procedures for the certification of TPC structures,*** and collection of new experimental data;
- ***assessment of the environmental impact according to ECO-quotation procedures***.

Main S & T results/foreground

The main results achieved at the end of the project are listed below:

Definition of a robust methodology for the design, material selection and manufacturing of thermoplastic composite components for helicopters.

In the first part of the project the fundamental issues to define a robust methodology to design and manufacture thermoplastic composite structural components for the aerospace sector were found and represented in explicit form, and a number of guidelines for the designer were collected in the first deliverables.

The advantages and disadvantages of thermoplastic composites in comparison with thermoset ones, regarding their physical, mechanical, processing, testing characteristics, were found and outlined: starting from this point the differences in design, processing and testing of these two different classes of materials were made clear. Consequently, the methodology currently used to design, manufacture and test the thermoset composites for aeronautic field was modified and integrated for thermoplastic composite materials. This new methodology is widely described in the first deliverable of the project, and was used with good results in the further parts of the project.

The objective of the second task of WP1 was the materials and process selection. At first the thermoplastic composite materials potentially usable for the aerospace sector were identified and analysed, and their datasheets were collected. On the basis of the materials properties, CETEX® PPS was selected to be used for the demonstrators manufacturing. CETEX® PPS is a thermoplastic composite provided by TENCATE, having carbon fibres T300 3K 5HS textile with double sided PPS film. This material was chosen for its high mechanical performances and for its relative easiness of process. Moreover thermoplastic composites provided by TENCATE are the only ones qualified for aeronautic sector. At last, there are some applications of the use of CETEX® PPS for the manufacturing of primary and secondary structures for aeronautic sector.

In the third task of WP1 the manufacturing process selection was carefully and deeply analysed. At first the main processes used to manufacture continuous-fibre reinforced thermoplastic component for aerospace sector were described. Among these processes, the compression moulding technique was chosen for the demonstrator manufacturing, because this technique allows a robust control process with good performances and high volume rates.

The compression moulding process was described in detail and the main guidelines to define optimised process parameters for compression moulding were outlined. Special care was ensured to the study of the main deformation mechanisms to be considered for the thermoforming of different component shapes. In fact the main limit of compression moulding process for advanced thermoplastic composites consists in the reduced geometry complexity of the components that can be manufactured without defects like wrinkles and thickness variations. For this reason some important numerical and experimental tools were described for the prediction of such defects, and among the several compression moulding techniques, the rubber forming technique was deeply analysed and described. In this technique one of the moulds used for the component forming is made with a rubber-like material, in order to ensure a suitable distribution of the required consolidation pressure, thus allowing an increase of the complexity of the shapes that can be manufactured with the compression moulding processes. For this reason it was used for the sponson fairing and radome manufacturing.

In the next image a photo of the aluminium-rubber moulds used for the manufacturing of the skin of the sponson fairing is reported.

Figure 1: aluminium-rubber moulds used for the manufacturing of the skin of the sponson fairing

Definition of a robust and high performing joining technique for advanced thermoplastic composites for the aerospace sector.

In the WP2 the joining methodologies for thermoplastic composites were analysed, focusing on joining techniques for aerospace sector. Even if bonded, mechanical and mixed bonded-mechanical joinings were considered at first, a special attention was paid to thermoplastic welding. In fact these techniques ensure the best performances in terms of mechanical properties and easiness of process, exploiting the possibility for thermoplastic materials to be melted and welded. The main results of this task were the complete survey of the joining technologies potentially of interest for aerospace sector and the selection of the joining technology that was used for demonstrator manufacturing, that is induction welding.

The induction welding technique is the most well promising technique to join thermoplastic composites in aerospace sector. Since the main disadvantages of this technique were the lack of experimental data and machine providers, Cetma (together with the Italian company SINERGO specialised on the development of new induction welding machines) decided to develop a new induction welding machine for continuous welding of thermoplastic composites. With this machine it is possible to obtain the working parameters suitable for thermoplastic composites welding and to make full-scale joinings.

Figure 2: New induction welding machine for thermoplastic composites developed by CETMA and SINERGO, internal view.

In this machine a robust control system was developed to ensure the wanted temperature distribution within the materials to be welded. The machine is equipped with a cooled cylinder, required to apply the consolidation pressure, and with an air cooling system useful to remove heat where required, for example in the edges in order to avoid the edge effect. The working parameters of the induction welding machine (such as working frequency and maximum power) were established through a number of tests carried out to fix the best compromise between frequency and power.

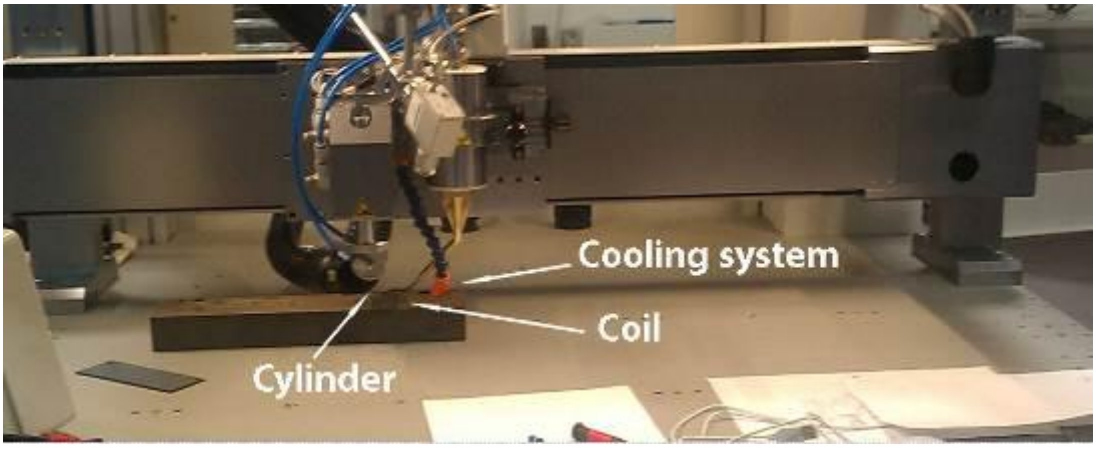


Figure 3: detailed view of the induction welding apparatus.

To optimize the above listed parameters for the demonstrator manufacturing (upper panel and sponson fairing), developing a robust methodology for the induction welded joining in aerospace sector, numerical analysis were carried out by means of Comsol Multiphysics Finite Element software with a multi-physics approach. The developed numerical model was verified through a huge number of experimental tests

In the next image the temperature distribution obtained for the induction welding process used for the upper panel manufacturing is showed.

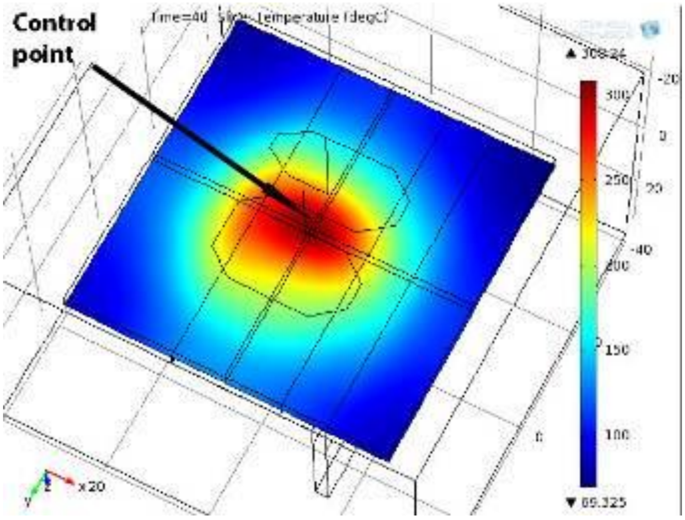


Figure 4: temperature distribution for the double-D coil, welding interface.

Finally, the optimized process parameters selection was confirmed by single-lap tests, in which shear strength values very close to the maximum values reported in literature were found. These high values of maximum shear strength are much higher than the maximum values that can be obtained using structural adhesives. It is important to notice that in the last part of the project the induction welding parameters were investigated and optimized also for PEEK-carbon and PEI-carbon thermoplastic composites, in order to have a complete survey of the capabilities of induction welding technique for the thermoplastic composite materials of interest for the aerospace sector.

The most important result of this task was the definition of a solid methodology for the design of the induction welding process, that was used for the design and manufacturing of the joinings required for the demonstrators.

Manufacturing of the three demonstrators

In WP3 the thermoplastic upper panel was designed and produced. The prototype is a significant portion of the existing Upper Panel of a Agusta Westland helicopter tail, and in the prototype manufacturing it is possible to evaluate all the process critical aspects that can arise during the manufacturing of the real part.

In the next image the final design of the Upper panel is reported.

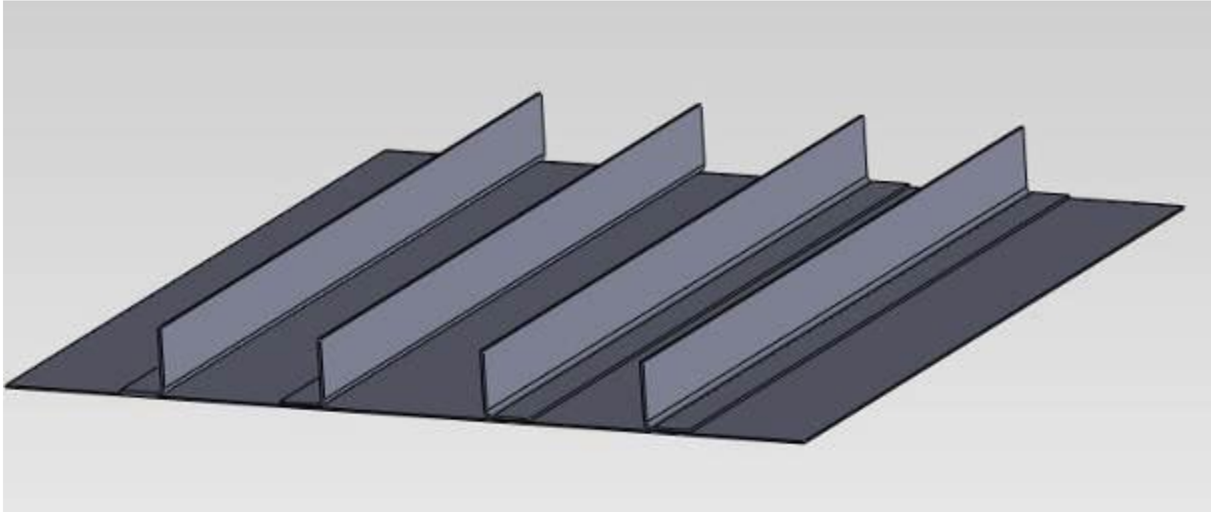


Figure 5: view of the Upper Panel demonstrator

The flat laminate of the Upper Panel was manufacture thorough isothermal compression moulding. Also the flat strips required for the L stringers were manufactured with the isothermal compression moulding process. Starting from these strips, the L stringers were manufactured through the not-isothermal compression moulding process.

In the next Figure a photo of the moulds fixed to the press plates is reported.

Figure 6: photo of the moulds used for the stringers manufacturing.

Finally the four stringers required for stiffened panel manufacturing were bonded to the flat laminate by means of the induction welding. The main result of WP1 was the complete manufacturing of the first demonstrator of the project.

In the next image a photo of the final stiffened panel is reported.

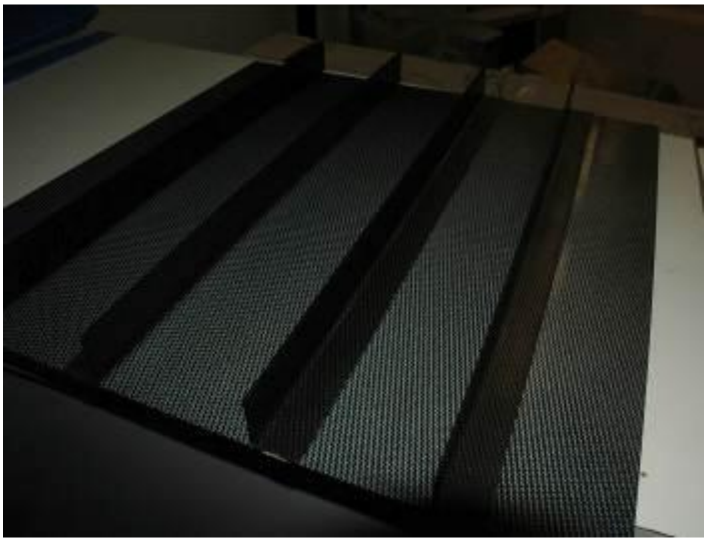


Figure 7: photo of the stiffened panel.

In the WP4 the sponson fairing was designed and produced. The sponson fairing demonstrator consists of a skin and two ribs. The thickness of the skin panel is 1.24 mm, while the thickness of the rib is 1.86 mm.

In the next image the final design of the Sponson fairing is reported.

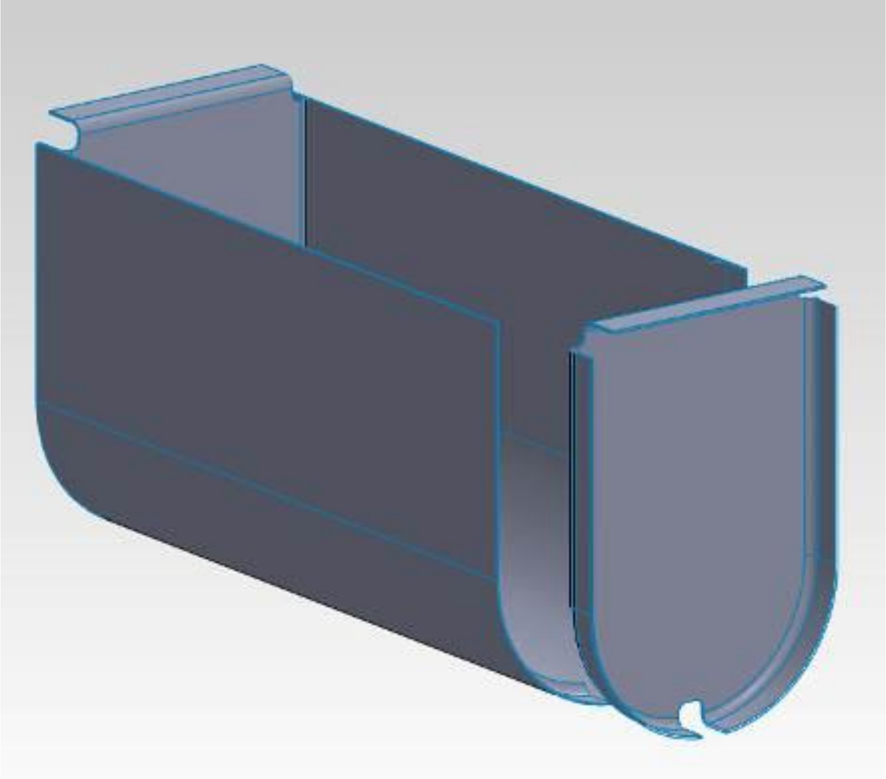


Figure 8: view of the Sponson Fairing demonstrator

The flat laminates of the skin and of the ribs of the sponson fairing were manufacture thorough isothermal compression moulding. The fundamental stages of such process are the same used for the upper panel. Starting from these laminates, the skins and the ribs are manufactured through the not-isothermal compression moulding process. The rubber forming technique was used to shape the skin of the sponson fairing.

In the next image a photo of the moulds required for skin thermoforming and fixed to the press plates is reported.

Figure 9: mould used to manufacture the skin of the sponson fairing.

In order to achieve the optimized definition of the manufacturing process for the sponson fairing the numerical tools developed in the first work packages were used.

In the next image the simulation of composite drapability on the rib of the sponson fairing is reported. Also the shape of the rubber mould was optimized through numerical analysis.

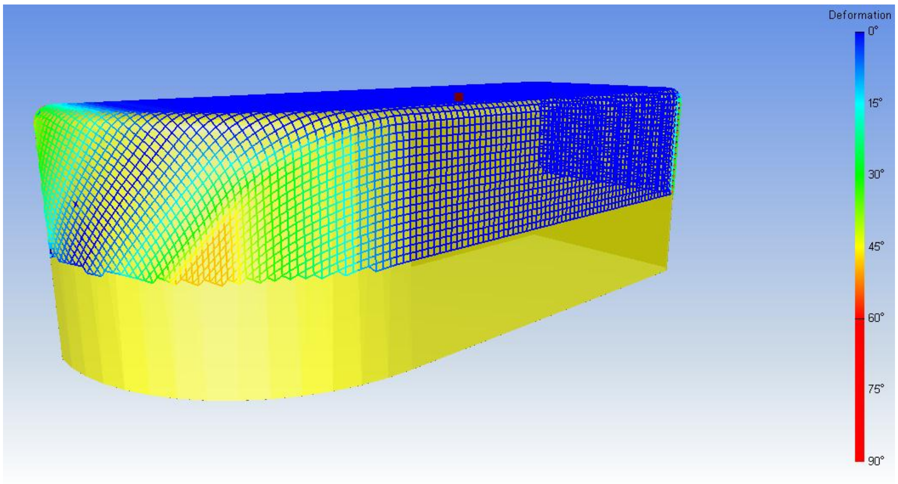


Figure 10: simulation of composite drapability on the rib of the sponson fairing.

For the manufacturing of this component different critical issues were studied and overcome:

Manufacturing of the skin of the sponson fairing → manufacturing of thermoplastic components with U-shape and high height/width ratio (see next image).

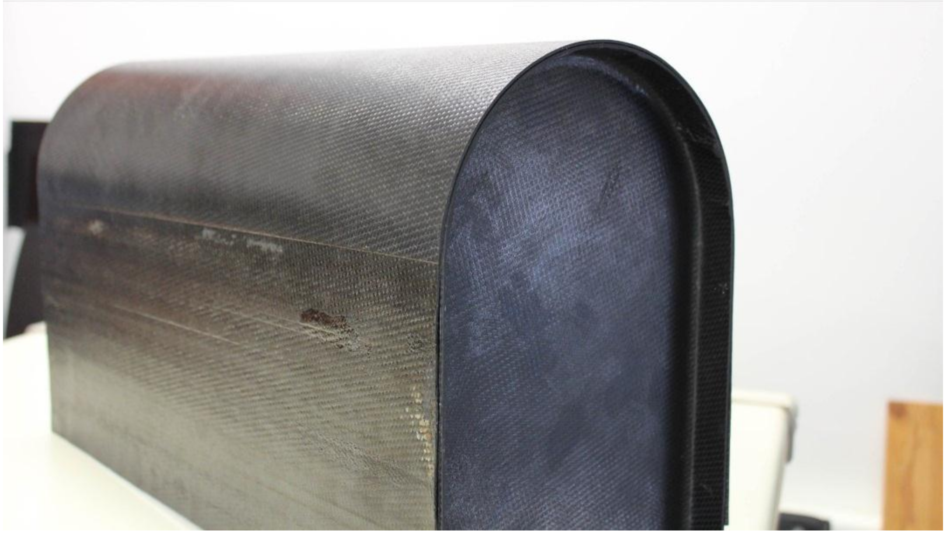


Figure 11: photo of the sponson fairing demonstrator.

Manufacturing of the rib of the sponson fairing → manufacturing of thermoplastic components with complex shape (see next image).

Figure 12: photo of the rib of the sponson fairing demonstrator.

Induction welding of the skin and the rib → induction welding of thermoplastic components with complex shape (see next image).

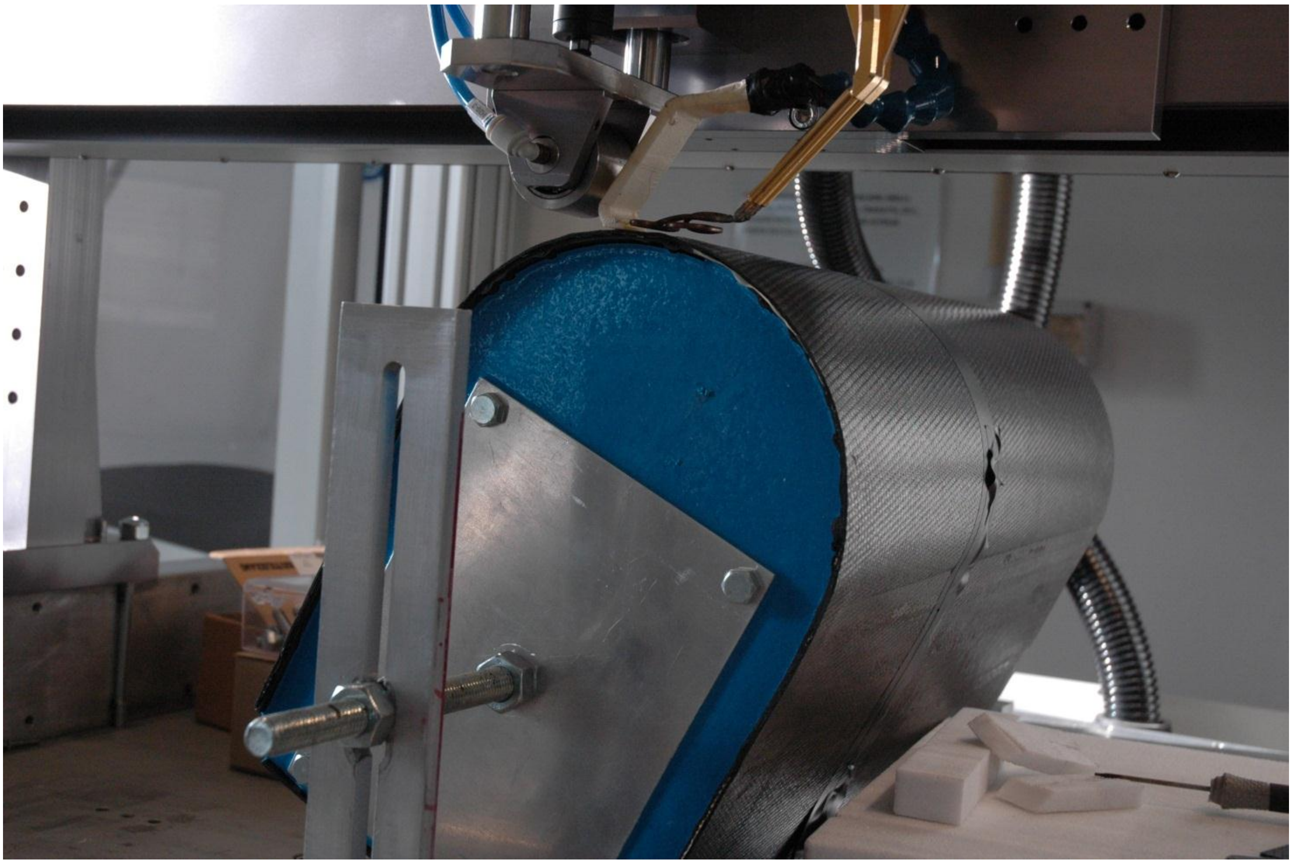


Figure 13: photo of the induction welding activities for the sponson fairing demonstrator.

In WP5 the radome demonstrator and its process were designed. Also in this case the rubber compression moulding technique was used (see next images), and numerical tools were used to optimize its manufacturing process.

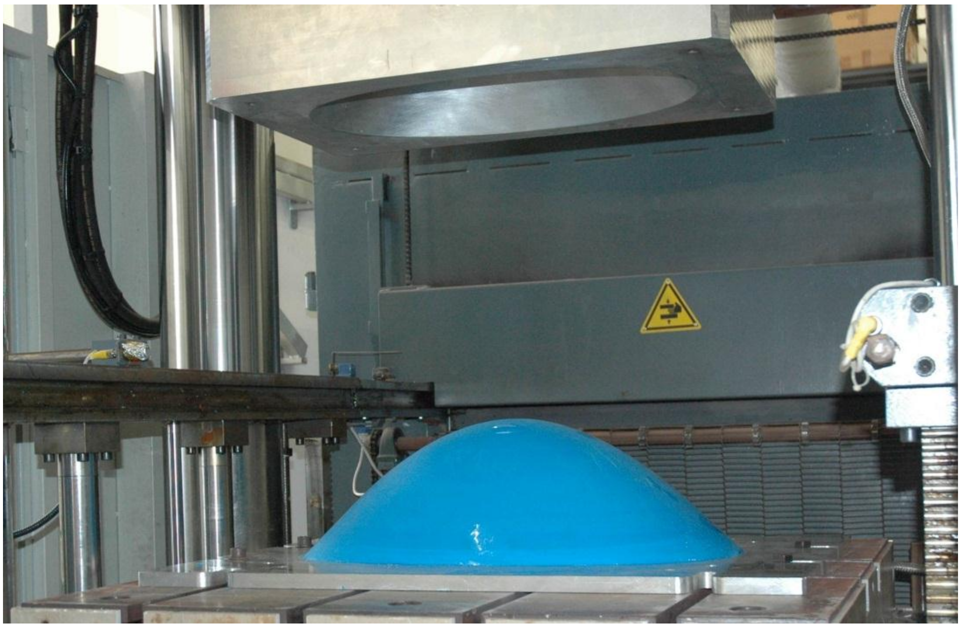


Figure 14: photo of the rubber forming process for the radome demonstrator.

Figure 15: photo of the radome demonstrator.

Evaluation and validation of the three demonstrators

In WP6 the plan of experimental tests required to evaluate the performances of the three thermoplastic demonstrators according the building block approach was defined. At first the tests on material coupons were defined and described. Then the test on sub-components were described, and finally the full-scale tests on the demonstrators were completely defined. The main result of the first task of WP6 is the definition of the test matrices to evaluate the performances of the three thermoplastic demonstrators.

In the last part of the project the test matrix to evaluate the performances of induction welded joinings manufactured with PEEK-carbon and PEI-carbon thermoplastic composites was defined.

In the second part of the project the activities related with evaluation of demonstrators performances were carried out. At first the NDI inspections were carried out according to the NDI plan on the three demonstrators (see next image).

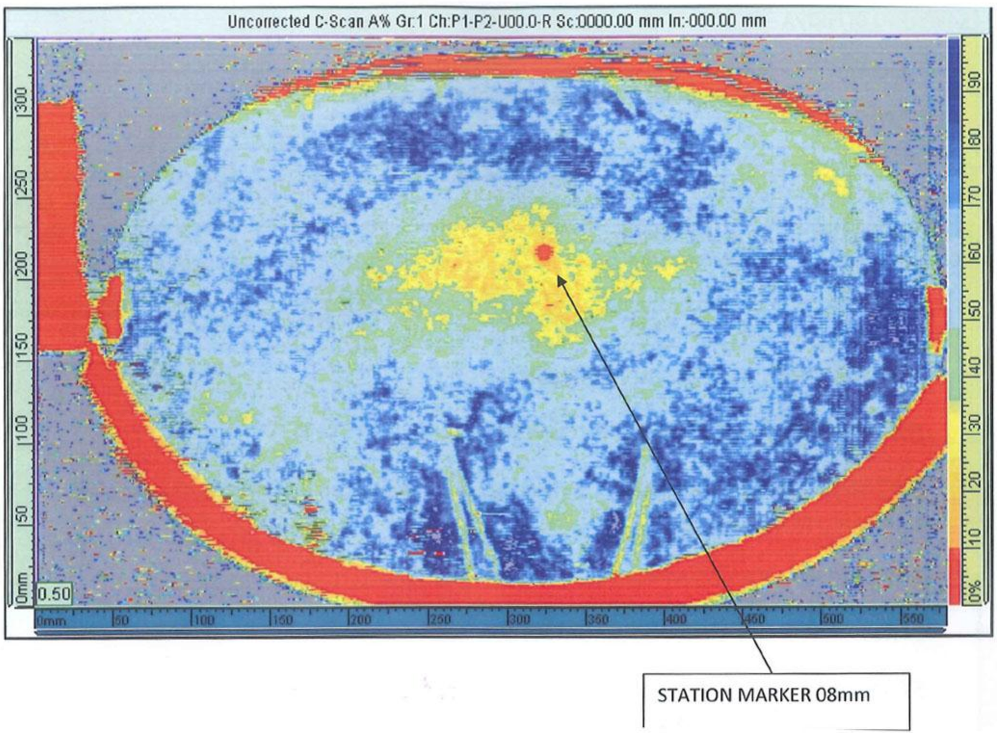


Figure 16: ultrasonic inspection of the radome.

The main results of NDI inspections are listed below:

- Ultrasonic method used for thermoset composites could be applied on the thermoplastic components;
- The three demonstrators satisfied the requirements of AW specification commonly used for thermoset composites.

In the WP7 the experimental tests required to investigate the material properties were carried out. At first the tests on material coupons were carried out: in this case the specimens were obtained from flat laminates with all the laminas oriented in the 0° direction, and the tests were carried out along warp and weft directions, according to DOT/FAA/AR-00/. Then the tests on sub-components were carried out according to the building block approach.

In the last part of the project the tests to evaluate the mechanical performances of the induction welded joinings manufactured with PEEK-carbon and PEI-carbon composites were carried out.

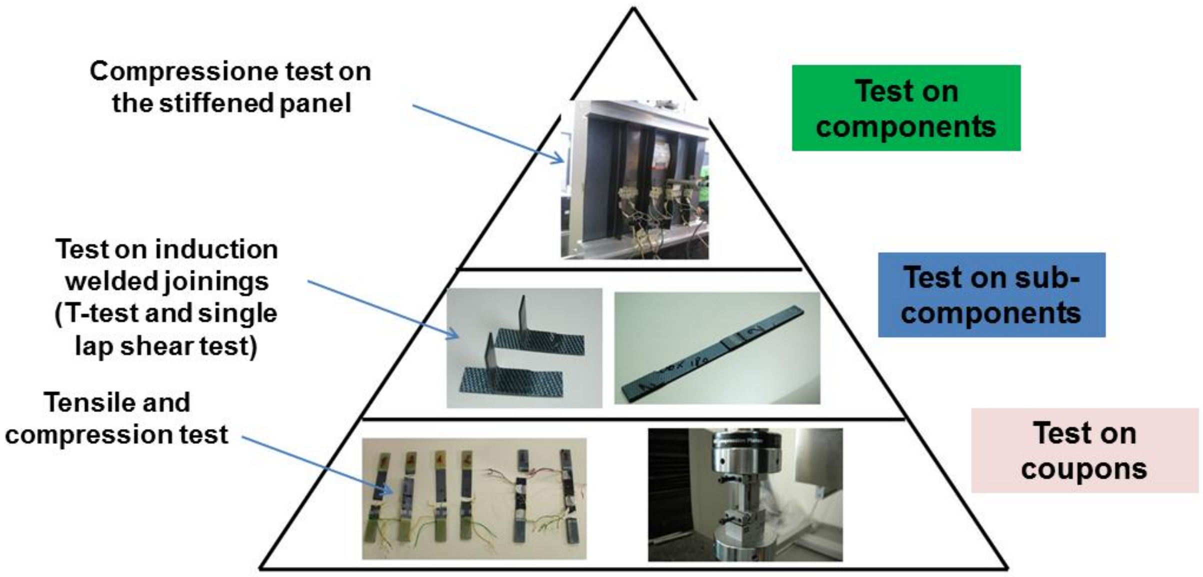


Figure 17: building block approach for the upper panel.

In the third task of WP7 the full-scale experimental tests to evaluate the mechanical performances of the three demonstrators were carried out. Both the stiffened panel and the sponson fairing were tested to evaluate their mechanical performances, such as buckling load and post-buckling behaviour.

Figure 18: photo of the compression test on the upper panel.

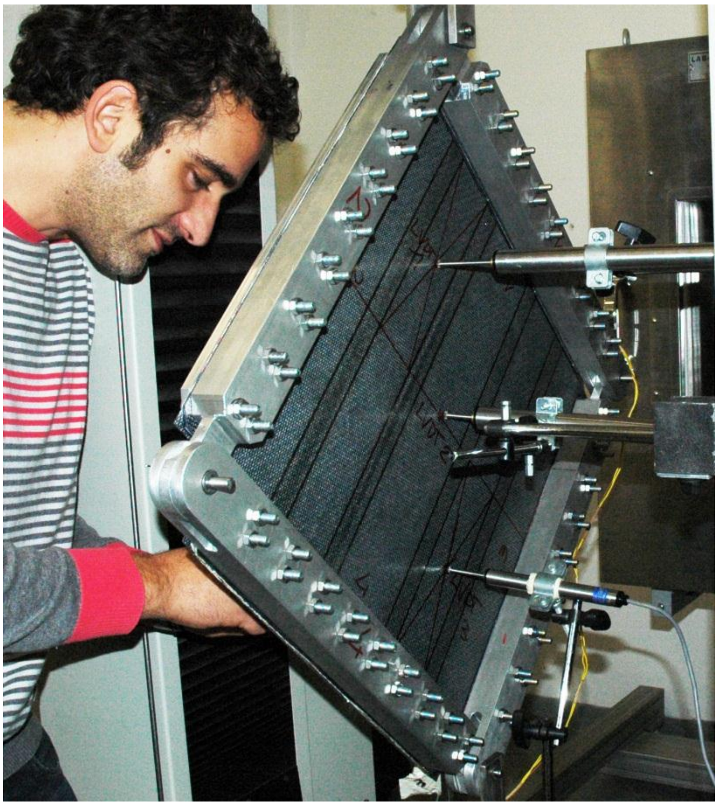
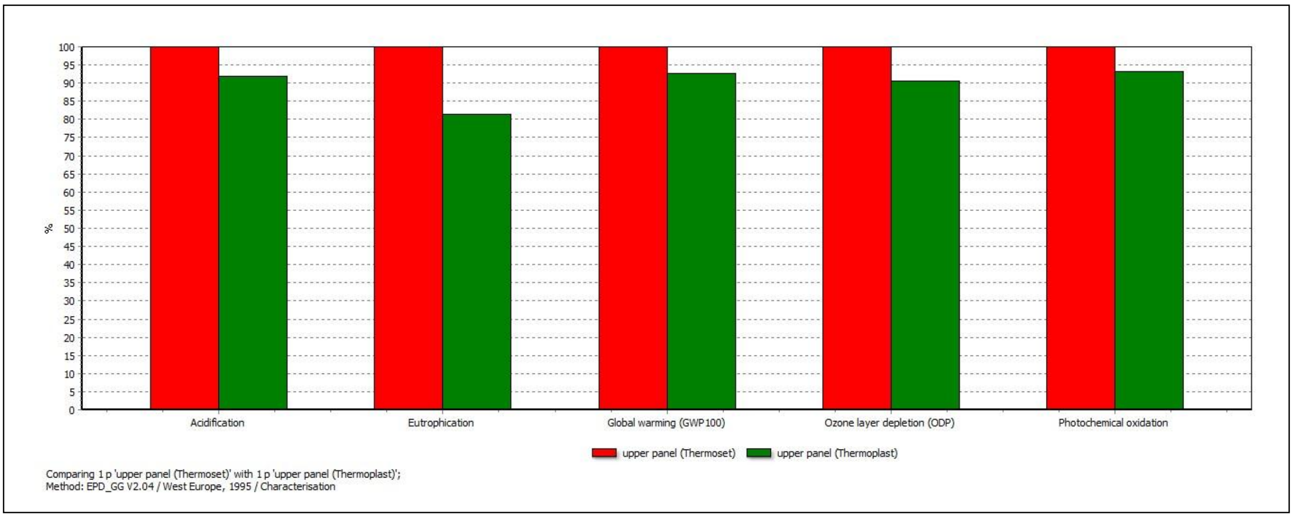


Figure 19: photo of the upper panel fixed on the picture frame.

Figure 20: photo of the compression test on the sponson fairing.

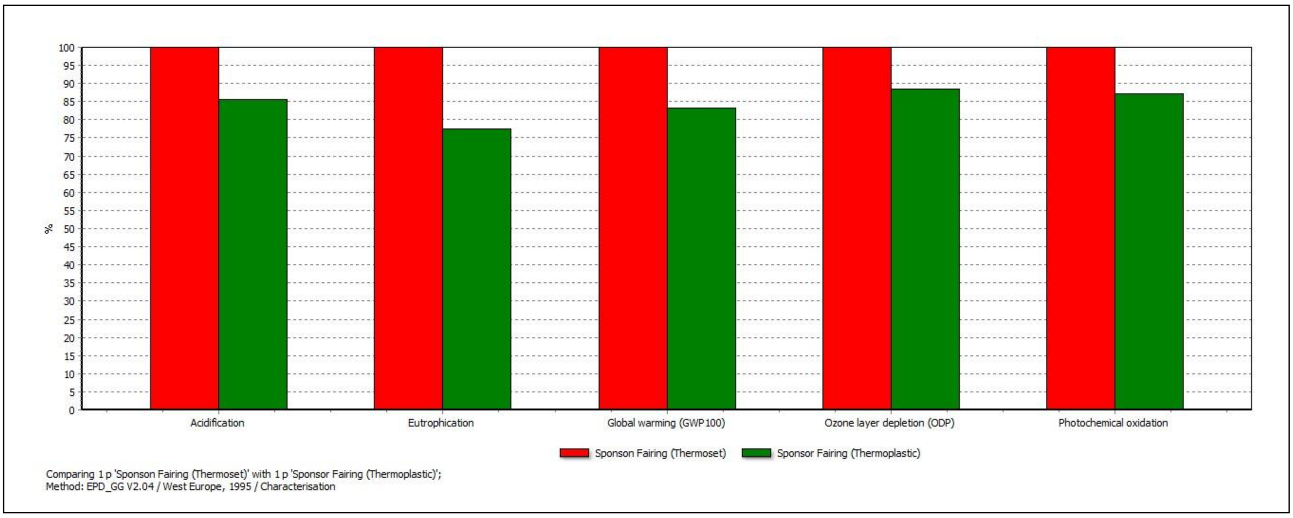
After the evaluation of mechanical performances the eco-quotation of the demonstrators was carried out. Life Cycle Assessment was conducted by applying the LCA methodology according to the guidelines given in the ISO 14040-43 series, with the *SimaPro 7* software from PRé Consultants (Netherlands).

In the next graphs the results of this activity are collected.



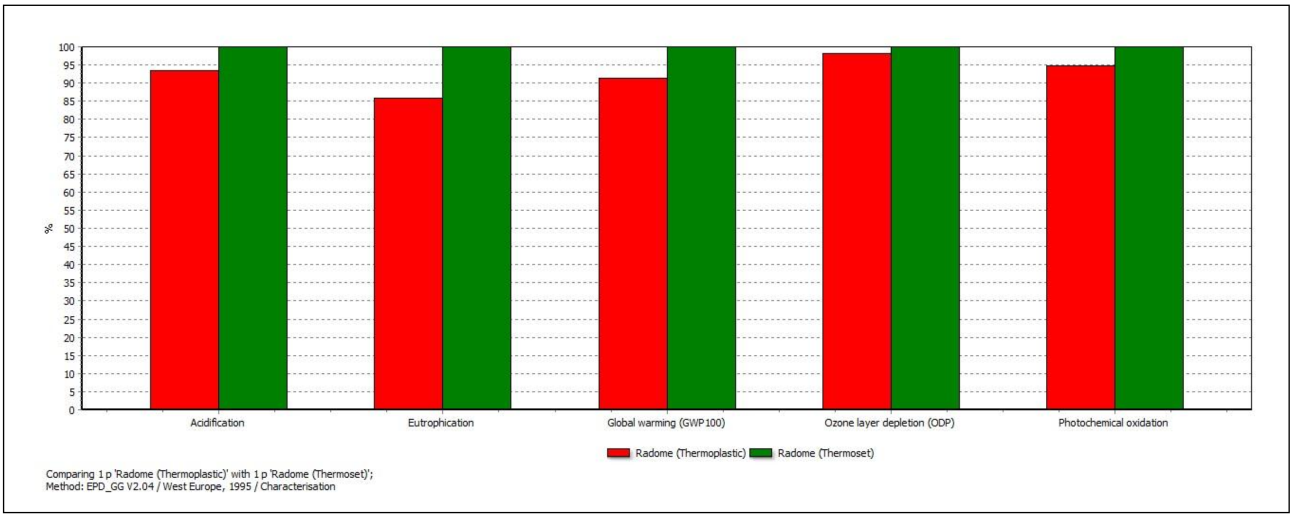
Comparing 1 p 'upper panel (Thermoset)' with 1 p 'upper panel (Thermoplast)';
Method: EPD_GG V2.04 / West Europe, 1995 / Characterisation

Figure 21: Environmental impact, Upper panel Thermoplastic Vs Upper panel Thermoset



Comparing 1 p 'Sponson Fairing (Thermoset)' with 1 p 'Sponsor Fairing (Thermoplastic)';
Method: EPD_GG V2.04 / West Europe, 1995 / Characterisation

Figure 22: Environmental impact, Sponson Fairing Thermoplastic Vs Sponson Fairing Thermoset



Comparing 1 p 'Radome (Thermoplastic)' with 1 p 'Radome (Thermoset)';
Method: EPD_GG V2.04 / West Europe, 1995 / Characterisation

Figure 23: Environmental impact, Radome Thermoplastic Vs Radome Thermoset

The results of the eco-quotation activities demonstrated that the thermoplastic demonstrators are characterized by a lower environmental impact in comparison with thermoset ones.

Potential impact and dissemination activities

A short and a medium-long-term impact is expected from the ECO-Fairs project. In fact, at the end of the project the following important results were achieved:

- Development of a methodology for the Design of complex shapes and functional structures with thermoplastic composites: the guidelines collected in the first WPs will be the basis for the design of new thermoplastic structures in the aerospace;
- Manufacturing of TPC demonstrators by means of out of autoclave processes: the three demonstrators were produced with cost effective and high volumes processes. For this reason a strong interest from the main companies in the aerospace sector was appreciated in the last part of the project, when the results of the project were discussed in scientific congresses and in technical meetings.
- Development of quality control procedures and development of characterization procedures for the certification of TPC structures: these important issues are fundamental for the exploitation of the thermoplastic composites in the aerospace sector. In fact the results of NDI inspections and of the mechanical tests were used to demonstrate the quality of the work performed. This approach was highly appreciated from the aerospace companies during the dissemination activities.
- Development of the new induction welding technique for thermoplastic composites: the development of a new induction welding technique for thermoplastic composites (PEE_carbon, PEI-carbon and PPS carbon composites), characterized by high performances and high automation level is one of the most important results of the project. The exploitation of this new technique could be soon extended at an European level. At the end of the project CETMA received five information requests from companies operating in the aerospace sector at an European level.
- Assessment of the environmental impact according to ECO-quotation procedures: the lower environmental impact of the thermoplastic demonstrators in comparison with the thermoset ones is an important added value, since this result matches with the aim of the GRC.

The objective of this task is to ensure that appropriate measures for absorption of results by the potential industrial end-users are put in place.

The actions taken for the dissemination of the results of the project are listed below:

- Submission to scientific congresses of papers discussing of the results of Eco-Fairs project;
- Participation to exhibitions;
- Participation to specifics meetings with important end-users in the aerospace sector;
- Publications in magazines focused on composites materials;
- Specific sections on CETMA website.

The following papers were submitted to scientific congresses:

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”.

Abstract

In this work the experimental and numerical investigation of continuous induction welding of PPS-carbon composites are reported. In order to develop a robust process for welding advanced composites for aeronautic sectors, the influence of the fundamental process parameters such as generator power, distance between induction coil and laminate, coil geometry and laminate lay-up on the heating rate and the heat distribution have been investigated in detail by means of finite element simulations carried out with Comsol Multiphysics software. The model was validated trough the comparison with the results obtained in stationary and continuous experiments, in which IR thermography was used to obtain full field temperature measurements of the heated surface. Optimized parameters for composites welding were found out, and the mechanical properties of the manufactured joinings were evaluated.

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Boeing's Phantom Eye flies on Hydrogen fuel. By courtesy of The BOEING Company

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Figure 24: brochure of the SEICO 13 congress.

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.

Abstract

Different attempts to develop new techniques to join thermoplastic composites were carried out in the last years, since the achievement of proper joining procedures is the fundamental key point to increase the use of thermoplastic composites in many industrial sectors, and especially in the aerospace sector. Besides the other welding and joining techniques, several studies were carried out on continuous induction welding of thermoplastic composites, since this technique can ensure very high performances, as high shear strength and fatigue properties, high resistance to peel stress, high efficiency and repeatability together with flexibility and good applicability at an industrial level. For this reason a new induction welding machine was developed by CETMA and SINERGO for continuous welding of thermoplastic composites. This apparatus, in which an innovative system was developed to ensure a proper temperature distribution within the different materials and geometries to be welded, was developed thanks to a huge work comprising numerical and experimental activities in order to optimize the parameters that have an influence on the final performances of the joinings. Thanks to the work carried out, and through the manufacturing of mid-scale prototypes, useful guidelines and procedures for induction welding of composites in the aeronautic sector were gathered.

Figure 25: brochure of the AIDAA congress.

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.

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Figure 26: brochure of the Business Improvement by performance simulations in A&D congress.

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

ABSTRACT

In this paper the joining of four L-shaped stringers on a flat panel made of Polyphenylene sulfide PPS/carbon is presented (Fig. 1). Welding is performed using an induction welding machine developed by CETMA, in cooperation with SINERGO (Vicenza, Italy), for continuous welding. This apparatus, in which an innovative temperature control system was developed, was designed thanks to a huge work comprising numerical and experimental activities in order to optimize the several parameters that have an influence on the final performances of the induction welded joints. In order to validate the process a stiffened panel made of (PPS)-carbon composite was manufactured. Compression tests were carried out on this component, and the experimental data were compared with the results of FEM analysis. The theoretical predictions well agreed with experimental data. The post-buckling behaviour of the panel, strongly dependent from the welded joints, showed that debonding between laminate and stringers occurred only after a break in one of the stringers .

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Porsche 918 Spider – CFRP Chassis structure By Courtesy of PORSCHE AG

By courtesy of the BOEING Company: COAD manufacturing demonstrator

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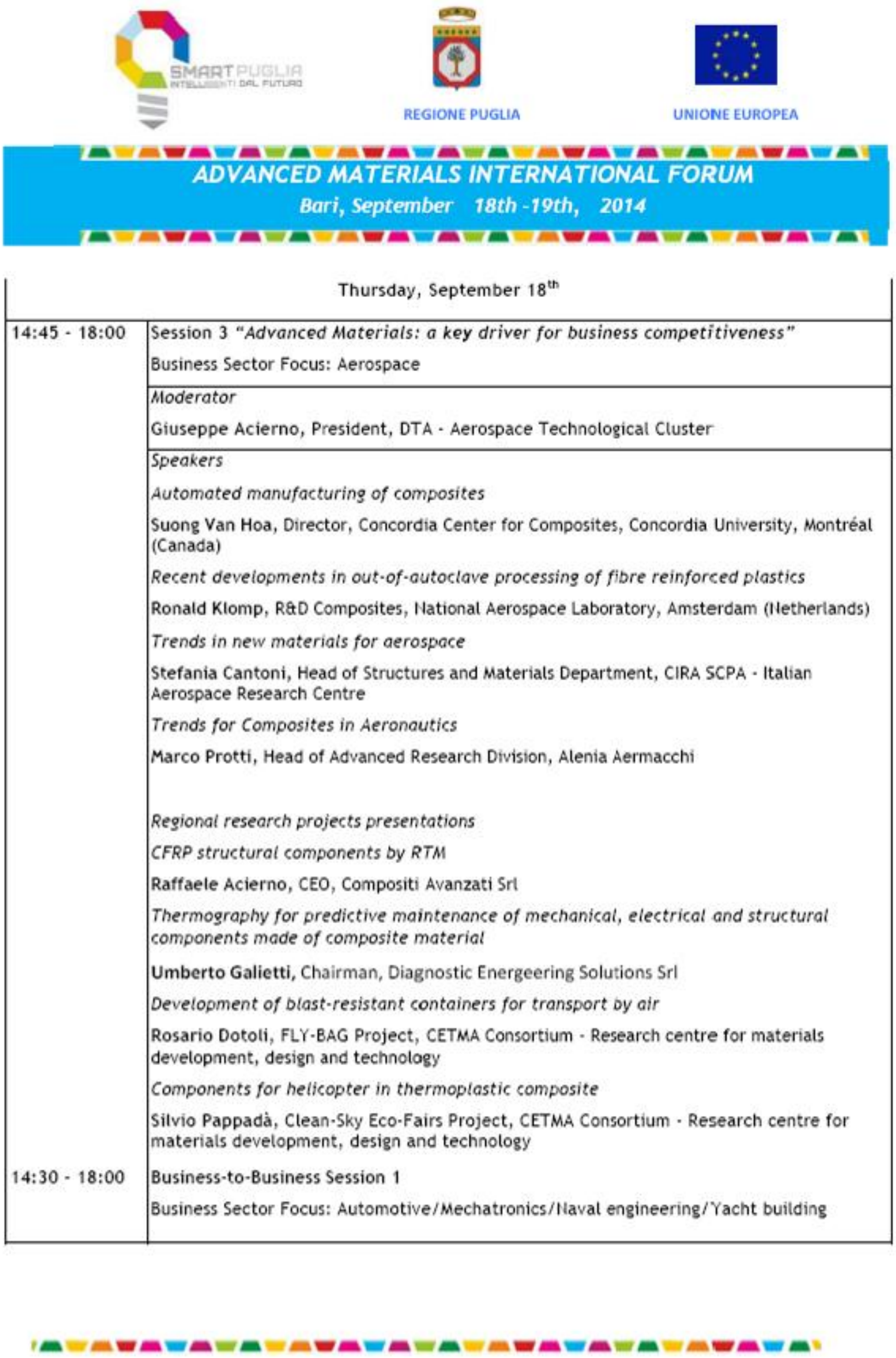
Figure 27: brochure of the SEICO 14 congress.

S. Pappadà, A. Salomi et al. “Clean-Sky Eco-Fairs Project: Components for helicopter in thermoplastic composite” Advanced Materials International Forum, 18-19 Settembre Bari (Italy).

Abstract

Within Clean-Sky Eco-Fairs project CETMA on behalf of AGUSTA carried out the Design, Manufacturing, Joining technology selection, Non Destructive Inspection (NDI), Mechanical characterization and Certification support for new Thermoplastic Structural components for helicopters. A robust methodology for the design, material selection and manufacturing of thermoplastic composite components for helicopters was developed and guidelines for designers were developed. The three demonstrators were designed and produced according to the technical specifications with a TRL6 Technology Readiness Level, by out of autoclave processes. Assessment of the environmental impact according to ECO-quotation procedures was also carried out.



SMART PUGLIA
INTELLIGENTI DAL FUTURO

REGIONE PUGLIA

UNIONE EUROPEA

ADVANCED MATERIALS INTERNATIONAL FORUM
Bari, September 18th -19th, 2014

Thursday, September 18th	
14:45 - 18:00	Session 3 *"Advanced Materials: a key driver for business competitiveness"* Business Sector Focus: Aerospace
	Moderator Giuseppe Acierno, President, DTA - Aerospace Technological Cluster
	Speakers *Automated manufacturing of composites* Suong Van Hoa, Director, Concordia Center for Composites, Concordia University, Montréal (Canada) *Recent developments in out-of-autoclave processing of fibre reinforced plastics* Ronald Klomp, R&D Composites, National Aerospace Laboratory, Amsterdam (Netherlands) *Trends in new materials for aerospace* Stefania Cantoni, Head of Structures and Materials Department, CIRA SCPA - Italian Aerospace Research Centre *Trends for Composites in Aeronautics* Marco Protti, Head of Advanced Research Division, Alenia Aermacchi *Regional research projects presentations* *CFRP structural components by RTM* Raffaele Acierno, CEO, Compositi Avanzati Srl *Thermography for predictive maintenance of mechanical, electrical and structural components made of composite material* **Umberto Galietti,** Chairman, Diagnostic Energeering Solutions Srl *Development of blast-resistant containers for transport by air* Rosario Dotoli, FLY-BAG Project, CETMA Consortium - Research centre for materials development, design and technology *Components for helicopter in thermoplastic composite* Silvio Pappadà, Clean-Sky Eco-Fairs Project, CETMA Consortium - Research centre for materials development, design and technology
14:30 - 18:00	Business-to-Business Session 1 Business Sector Focus: Automotive/Mechatronics/Naval engineering/Yacht building

Figure 28: AMIF programme.

A paper was submitted to the “Aerospace Science and Technology” scientific paper.

Elsevier Editorial System(tm) for Aerospace Science and Technology
Manuscript Draft

Manuscript Number:

Title: Fabrication of a thermoplastic matrix composite stiffened panel by induction welding

Article Type: Full Length Article

Keywords: induction welding; Poly-phenilene sulfide; heat transfer; process modeling; stiffened composite laminate

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Abstract: In this work, the experimental and numerical study of induction welding devoted to the fabrication of a composite stiffened panel, representative of a typical aeronautic sub-component, is presented. A thermoplastic matrix composite, poly-phenilene sulfide (PPS) reinforced with carbon fibers, is used. The influence of the fundamental process parameters, such as generator power, distance between induction coil and laminate, coil geometry and laminate lay-up on the heating rate and the heat distribution was analyzed applying finite element simulations. The model was validated through the comparison of experimental and model results obtained in static experiments. Optimized parameters for composites welding were found out, and the mechanical properties of the welded joints were evaluated by single lap shear and pull off experiments. Finally, a prototype panel made of a flat laminate stiffened with four "L" shaped stringers is fabricated by continuous induction welding, exploiting modeling and experimental results. A C-scan of the panel was also performed.

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Wide experience in the area of thermoplastic composites

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Wide knowledge in fabrication and characterization of aeronautic composite structures

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Figure 29: report of paper submission to the scientific paper “Aerospace Science and Technology”

In March 2013 Cetma participated to JEC exhibitions with an own stand, in which it was possible to show the results of Eco-Fairs project.

Figure 30: brochure of the JEC 2013 exhibition.

In the next photos the CETMA stand at JEC 2013 is shown.

Figure 31: photo of CETMA stand at JEC 2013.

Figure 32: photo of CETMA stand at JEC 2013.

Figure 33: photo of CETMA stand at JEC 2013.

Cetma discussed about the results of the Eco-Fairs project in specific meetings and web-meeting with some important end-users in the aerospace sectors. The most important meetings are listed below:

- Alenia Aermacchi, Pomigliano d'Arco, September 2013, "Out of Autoclave technologies at CETMA for aerospace sector";
- Alenia Aermacchi, Foggia, November 2013, "Out of Autoclave technologies at CETMA for aerospace sector";
- TPRC, Thermoplastic Composites European Consortium, Web-meeting, December 2013, "Induction welding in aerospace sector".

Cetma presented some of the results of the Eco-Fairs project (induction welding machine and upper panel) in an advertising space in the magazine "Compositi", Tecnedit Editor.

CETMA

is the right solution to speed up your business

New induction welding equipment for advanced thermoplastic joining and repairing

Thermoplastic composite prototypes for transports

Out of autoclave technologies for aerospace sector

Testing on materials and components

Resin Transfer Moulding for biobased materials

CETMA Centro di progettazione, design & tecnologie dei materiali
S.S. 7 Km 706+030 - Cittadella della Ricerca - Brindisi - ITALY - tel. +39.0831.449111 - info@cetma.it - www.cetma.it

Figure 34: advertising space in the magazine "Compositi".

Moreover:

A paper was submitted to the following magazines:

- the No87 March 2014 / jec composites magazine (see enclosures);
- the No32 Giugno 2014/composite magazine (see enclosures).

Specific sections on the results of the Eco-Fairs project were dedicated on the Cetma website, www.cetma.it.

Submission of an European patent on Induction welding equipment

Patent

"INDUCTION MACHINE FOR BONDING POLYMER-MATRIX CONDUCTIVE COMPOSITE MATERIALS AND BONDING METHOD FOR SAID MACHINE"

European Query nr. 14167453.1 -7 May 2014

Case Number E1757/14-EP

The present invention relates to an induction machine for bonding elements of electrically conductive polymer-matrix composite materials…