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Penetración de composites de fibra de carbono con matriz termoplástica en estructuras aeroespaciales

RESUMEN

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AFP

FIDAMC *(Fundación para la Investigación, Desarrollo y Aplicación de Materiales Compuestos)*, está investigando, con el apoyo de distintos proyectos financiados por el gobierno español e iniciativas dentro del marco del CLEAN-SKY, para demostrar que los composites de matriz termoplástica pueden ser fabricados mediante procesos automatizados sin autoclave e integrando en un solo paso la piel y larguerillos mediante co-consolidación in situ, es decir fundiendo juntos ambas partes y así crear la estructura integrada..

Nuestro centro se encuentra inmerso en un proyecto de especial interés para conseguir una solución completa de fabricación de paneles de ala en termoplástico, usando una máquina de posicionado automático de fibras (AFP *Automatic Fiber Placement*) con un sistema asistido de láser como fuente de calentamiento, que será validado con ensayos en tierra y vuelo en el año 2020.

Esta ponencia da una visión de los diferentes proyectos para el desarrollo de la laminación automática y co-consolidación de una estructura integrada y del desarrollo en paralelo del cabezal de laminación de material de fibra de carbono impregnado con PEEK, que se ha llevado a cabo con la colaboración de MTorres. Se pretende mostrar la evolución de la máquina prototipo de una sola mecha hasta la configuración actual del cabezal multimecha.

Finalmente se detalla la ejecución del demostrador de factibilidad de un panel típico de ala con rigidizadores integrados por el método de consolidación citado.

Thermoplastic composite penetration in the aerospace structures

ABSTRACT

Keywords:
Thermoplastic
In situ Consolidation
Aeronautic structure
AFP

FIDAMC*(Fundación para la Investigación, Desarrollo y Aplicación de Materiales Compuestos)* , has been investigating different technologies, under the frame of several research projects funded by Clean Sky initiatives and Spanish governmental entities, in order to demonstrate that thermoplastic can be directly manufactured via automation without autoclave consolidation and the full integration of the structure by co-consolidation method fusing together the skin and stringers in only one melting step.

Our Center is currently involved in an interesting project with a complete manufacturing solution of a thermoplastic wing skin using Automatic Fiber Placement (AFP) with assisted laser system as heating source techniques. This new Out-of-Autoclave procedure will be validated with ground/flying tests in 2020.

This paper provides an overview of several research projects aimed to develop the automated lamination and in-situ co-consolidation technology and includes a review of automated methods to lay up PEEK prepreg from the first AFP head, in cooperation with the Spanish supplier MTORRES and installed six years ago in FIDAMC, the evolution of this machine and the up-to-the minute configuration of new Multi-tows head to produce the feasibility demonstrator panel with co-consolidated "T" shaped stringers and scale up the methods to the final stiffened wing panel to incorporate in Clean Sky 2 as Flight test Bed developed by Airbus.

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1 Introduction

The use of thermoplastic matrix in carbon fiber reinforced components has been growing continuously in automotive and aerospace applications. These composites are becoming the material of choice for replacing traditional metallic materials because higher strength to weight ratios, better chemical and impact resistance and design flexibility. The future market of thermoplastic components will increase in the next years.

Besides thermoplastics have recognized aspects such as excellent FST (Fire, Smoke, and Toxicity) properties, higher mechanical properties, damage tolerance and inherently superior fatigue performance, chemical resistance, infinite shop life, weldability, reuse of material and shorter manufacturing cycles compared to their competitor thermosets. Thermoplastic resins offer a high potential not only regarding material properties, but also in order to reduce processing time, logistic, operation and life cycle costs.[1]

Considerable research efforts has been devoted by Airbus and Boeing to adopt this class of materials in flight-critical structures starting with small parts such as clips /cleats and interior structures, floor panels and wing leading edges in A340/600 and A380 using mainly process technologies such as stamping and thermoforming, autoclave molding, diaphragm forming, filament winding and pultrusion and fusion joining technologies as electrical resistance, ultrasonic and induction welding. The main barrier to reach cost-effectively manufacture large thermoplastic aerostructures like wing skins and fuselage panels with acceptable level of porosity is the automatization with out-of-autoclave methods. In-situ consolidation process is currently the main goal of most research and technology projects on thermoplastic materials. The aim of this process is to avoid the use of autoclave and to reduce the number of processing steps, and consequently reduce the cost considerably, while maintaining competitive properties [1], [2].

FIDAMC has investigated its out-of-autoclave (OoA) thermoplastic composite technology over several years under several research projects funded by Clean Sky initiatives and Spanish governmental entities, aiming that thermoplastic can be directly manufactured via automation without autoclave consolidation and the full integration of the structure by co-consolidation method fusing together skins and stringers in only one melting step thinking in large wing and fuselage panels [3].

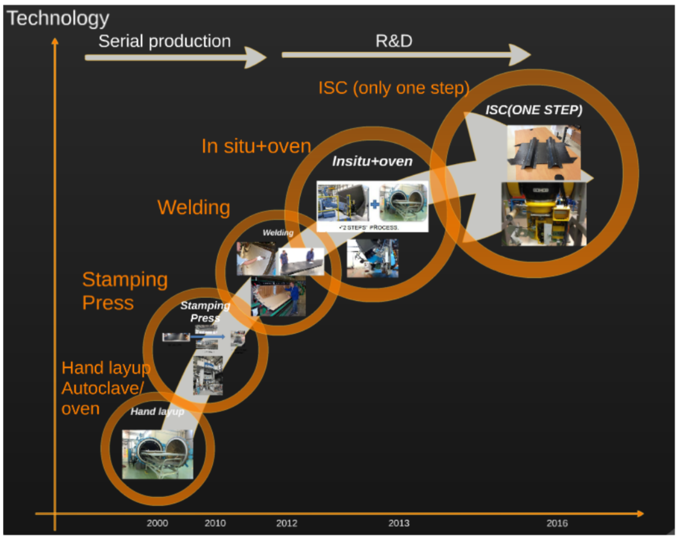

Figure 1. Evolution of technology level.

2 Thermoplastic composites technology in FIDAMC

Necessary to these projects has been the development of a specific Thermoplastic Automated Fiber Placement machine, carried out together with Spanish supplier MTORRES and installed at our facilities seven years ago.

2.1 Machine description

Existing machine, shown in Figure 2, consists in a laying up head that performs the process to melt, deposit and cool the thermoplastic unidirectional tapes, ply by ply on a tool. The process requires a continuous heating source by diode laser. An infrared camera is incorporated to the head to measure the temperature at the focal spot in the NIP (contact with roller) and length in the substrate and adjust the power and the angle of the laser optics. Other components of the machine head include an online compactation roller. Both incoming tape and substrate are consolidated by the action of this roller under controlled heat and pressure.

The parameters to be controlled during the process to achieve enough consolidation were the lamination speed, temperature and thermal history and pressure. Laser profiles and velocity of the system establish the thermal history of the material. The velocity is direct related with the exposure time of the material to temperature, and with the heat transfer through the whole laminate.[3]

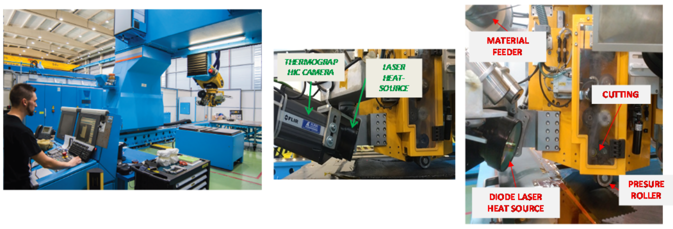

Figure 2. Thermoplastic machine characteristics.

2.2 Process window methodology

The parameters optimization *are* conducted by the methodology shown in Figure 3, with a study on mechanical and physical properties of in-situ consolidation of laminate. The evaluation of these resuls *are* compared to specimens built in autoclave or hot plate press.

The critical issue in the consolidation is to support the temperature necessary for the process a certain time. Laser profiles and velocity of the system establish the thermal history of the material. The velocity is direct related with the exposure time of the material to temperature, and with the heat transfer through the whole laminate [3].

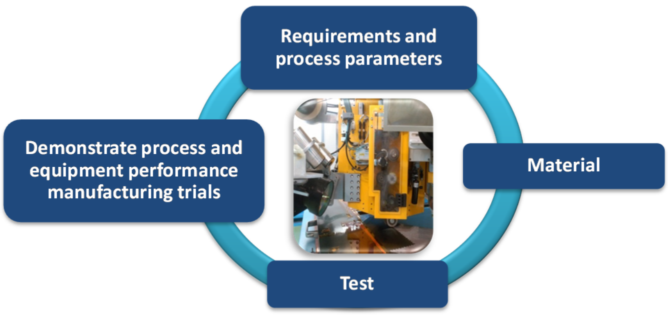

Figure 3. Process window methodology.

Standard In-plane Shear Strength (IPSS) tests are used to assess the final degree of consolidation (DOC) in comparison with autoclaved samples because it is the dominating factor in the matrix-interface performance. Results are shown in Figure 4. The data show that specimens have 35-40% crystallinity and require neither further post-consolidation step nor vacuum bag and autoclave processing.

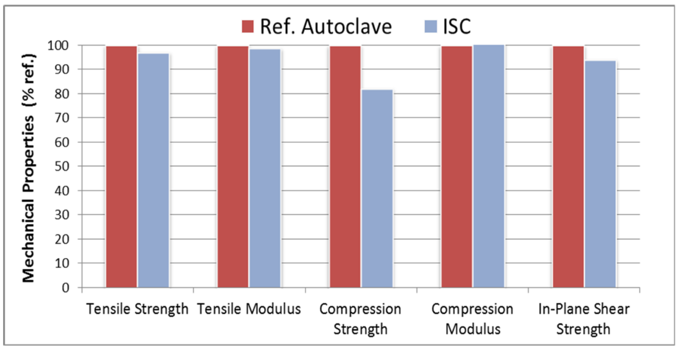

Figure 4. Results of mechanical strength of ISC laminates in comparison to laminates manufactured in autoclave.

3 Full integration of structures

Following we *are* working on the evolution of the head and feasibility panels have been built to get enough maturity and fix the process window. More complex structures with integrated stringers have been manufactured by co-consolidation, that is to say, fusing together skin and stringers in a single melting step.

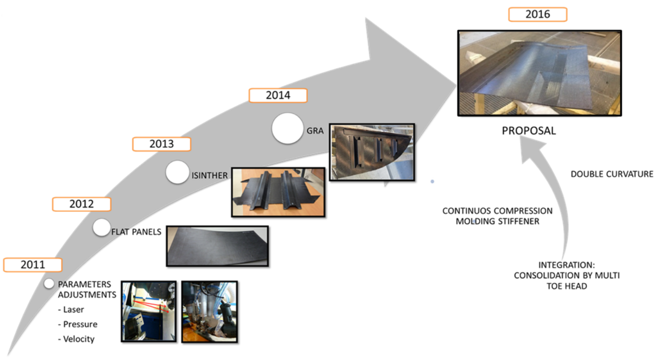

Figure 5. Evolution of thermoplastic structures with the improvements incorporated in the machine.

First demonstartor panel, called ISINTHER, has been developed with funding from Clean Sky 2 and shows a very large structure manufactured by co-consolidation process, combining stringers and skin. Stringers were made by flat laying up using AS4/PEEK (APC2) thermoplastic unidirectional (UD) tapes supplied by Cytec/Solvay. These blanks are thermoformed in a stamping press equipped with infrared lamps at 400ºC. Omega stringers *are* chosen to simulated typical fuselages structure. This demo is produced with a heated, modular lay up tool with incorporated vacuum system where stringers *are* located in holes and covered with mandrels inside to create a flat surface, and skin is laminated above them by automated fiber placement machine with assisted laser. The complete process is illustrated in Figure 6.

Figure 6. Co-consolidated full stiffened structure process.

Next step is a full demonstrator panel with two co-consolidated stringers and "L" shape with integrated joggless representative of a cockpit frame using the same process and molds of ISINTHER. All that needs is some changes in the stiffeners mandrels. This part is fitted inside a cabin for ground test. See details in Figure 7 [4].

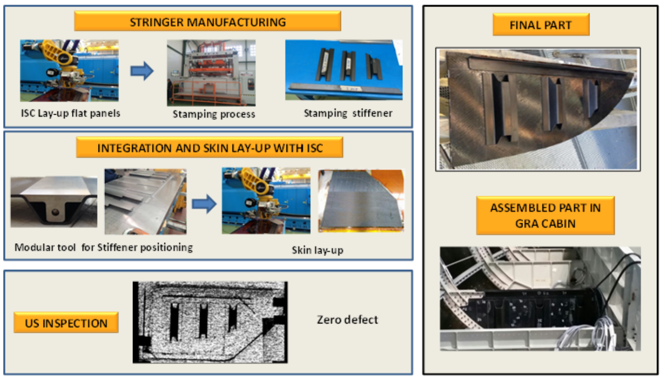

Figure 7. Co-consolidated cockpit frame using the target technology.

4 Industrializing the process

Mature and robust process has been got with the knowledge achieved with the related activities. FIDAMC with the support of Airbus and new funding from Clean Sky2 has launched the OUTCOME project in order to produce of a large stiffened wing skin panel, incorpored into the wing of CS2 regional aircraft, and ground and flight test in 2020.

We have the intention to scale the process with continuous improvements in lay up productivity with a multitow head, exactly eight tows, that will be incorporated in the existing MTORRES machine and with a new advances in the laser technology, optic and process maturity.

The technology advances are shown with the manufacturing of a feasibility demo with a prototype 8-tows head installed in a robot in MTORRES facilities in Pamplona on last september 2016. Different stringers styles ("T" shape) are produced using autoclave consolidation. An overview of the feasibility demo with target technology described previously is shown in Figure 8.

Figure 8. Feasibility demo of full stiffened wing panel with new concept of 8-tows machine.

5 Conclusions

From these activities, the following conclusions can be drawn:

1. Thermoplastic composite is a real opportunity to reduce production costs during the next years and is a potentially green technology.

2. The selected manufacturing process has performed as expected and until now the results look very promising.

In outline, the first manufacturing trials performed on September 16 have shown that full integrated wing panels can be manufactured via laser assisted automated fiber placement technology by co-consolidation of stringers with skins and without autoclaving post-consolidation step.

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