ACTIVITIES ON IN-SITU CONSOLIDATION BY AUTOMATED PLACEMENT TECHNOLOGIES

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Abstract

Fidamc has been involved in the development of thermoplastic composites technologies for aerospace structural applications to approach the automation of the lamination process with laser as heating source added in automated tape placement machine. The challenge has been qualifying a manufacturing method of a thermoplastics composite part in just one step, called "in-situ" process, without the participation of autoclave. This has led to develop a specific Thermoplastic placement machine with the participation of Spanish equipment supplier MTorres.

Therefore this paper will discuss the recent developments in Fidamc for manufacturing technological demonstrator that incorporates composite concepts design consisting in a skin panel with co-consolidated stringers.

1. Introduction

The widespread use of aeronautical composite structures for different aircraft parts, including primary ones like wings and fuselages, is a fact.

Within this composites generalization, the use of thermoplastic matrix materials is increasing on new designs due to their greater damage tolerance under low speed impact, better high temperature and fire behavior, chemical resistance, low moisture absorption, durability, potential reparability and greater recyclability than thermoset composites.

Thermoplastic composites processes, in serial production, need still a manual bagging operation, hand layup and expensive autoclave cycle, one of the most advantages of thermoplastics over thermosets is cycle time reduction. Fidamc has been researching for three years in automatic positioning process called consolidation in situ, in the first part of the investigation there was necessary the use of the second cycle in oven. Fidamc, currently, has worked in improvements in the process and, as results, has been manufactured a thermoplastic demonstrator in one step. In the figure 1 it is shown the technological evolution on thermoplastic material.

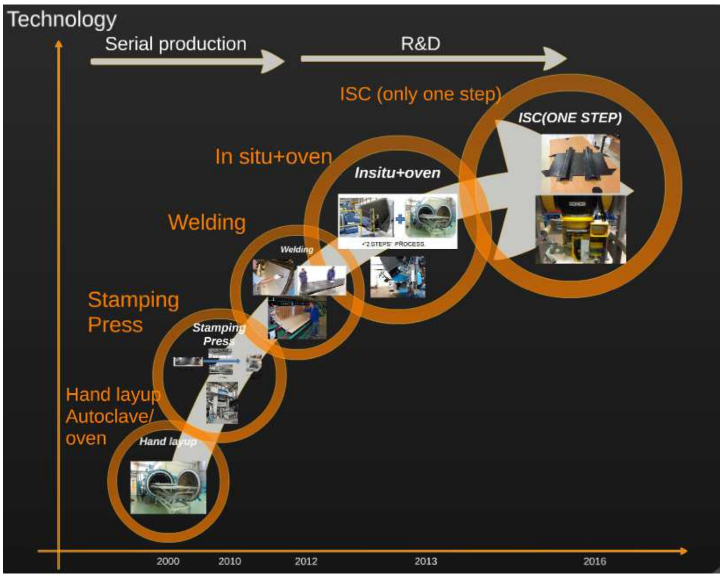

Figure 1. Technological evolution

The following challenges showed in the figure 2 have been achieved by Fidamc:

Figure 2. Technological challenges. [1]

The European ISINTHER project is dedicated to development and optimization of thermoplastic composites technologies in one step, as co-consolidation and reparability process. Both environmental and economic factors have been evaluated too, because nowadays environmental protection is a global priority than demand compromises and responsibility.

The main aim of this paper is describing the development tasks of a typically aircraft structure consisting of a flat skin stiffened by Ω-section stringers in thermoplastic material. The following topics have been investigated:

- ✓ Improvement of the process window of in situ consolidation automated fiber placement machine.
- ✓ ISINTHER demonstrator manufacture:
  - o Manufacture stringer by thermoforming process
  - o Optimization of the co-consolidation process
- ✓ Assessment of the "in-situ (ISC) automatic consolidation of thermoplastic material" environmental benefits, applied to the manufacture of a stiffened structure.

2. Automated thermoplastic fiber placement process with laser heating system

2.1. Machine description

Machine consists in a heated head that incorporates a process to MELT, DEPOSIT and FREEZE the thermoplastic unidirectional tapes, ply by ply on a mandrel tool. The process requires a continuous heating source by laser type Diode, because its high energy, controllability and high efficiency. [2]
Besides the heat sources, the components of on line consolidation roller movable layup head, cooling system and control devices.

Figure 3. Head of laser assisted Thermoplastic tape placement machine in FIDAMC

In the figure 3 it is shown the head of prototype machine develop by MTorres and Fidamc. A laser optics with scanner (not a fixed optic) in order to change the distribution of the radiation between incoming tape and substrate can be applied and achieve the optimum processing profile of temperatures along the lamination. Both incoming tape and substrate under controlled heat and pressure are consolidated by the action of the consolidation roller and finally under pressure of a second roller, the microstructure is frozen in a cold area to lower temperature under crystallization point to reach adequate mechanical properties.

2.2. Methodology

The methodology for development and improvement the thermoplastic automated placement technology is shown in the figure 4.

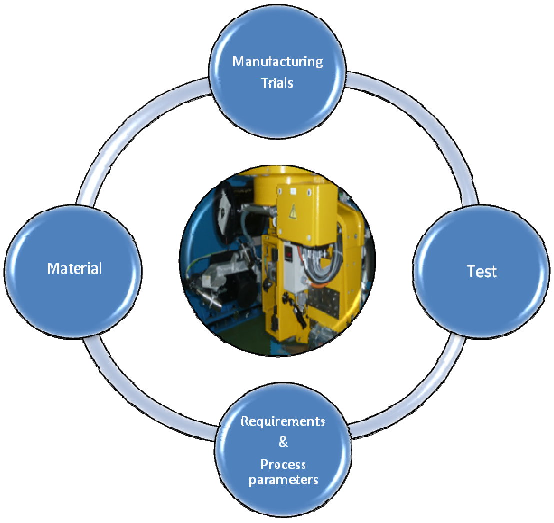

Figure 4. Methodology graph

2.3. Material

The material that was used throughout the investigation is Cytec APC2/AS4. PEEK, and its characteristics are 1/4´´width UD slit tape, prepreg areal weight 220 g/m2 and 34% matrix content weigh, fibre areal weight 145 g/m2, Nominal thickness (60% FVC) 0.135 mm.

2.4. Experimental Description

The variables to be controlled and improved during the process to achieve enough consolidation are: temperature, pressure and speed

The system of pressure has been modified throughout the time, one has worked with metallic heated rollers, with rubber rollers or using only one roller or a system of two independent rollers. High pressures are not required as several studies have shown that pressure is the least important of the primary bond parameters for interfacial bond strength. [3][4].

One of the most important points for the process of 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. The maximum placement velocity is limited by the time required to achieve intimate contact.

When we have increased the intimate contact time and temperature for the same velocity, best mechanical properties are achieved in the in situ consolidation process.

2.5. Design Concepts

Some different concepts have been manufacture to evaluate the capacities of the automated thermoplastic fiber placement machine, ply dry-off and joggles. In the figure 5 a flat panel appears a slope with a ramp ratio of 1:10 and the another one with ramp ratio of 1:20.

Figure 5. A panel with two ramps ratios

3. Technological demonstrator

A technological demonstrator representative of a wing skin has been manufacture, it is a flat panel, big thickness, integrated stiffeners, hollow hat stringers with omega shape. .
The main challenge of this demonstrator is to show the feasibility of joining the stringers and the skin.

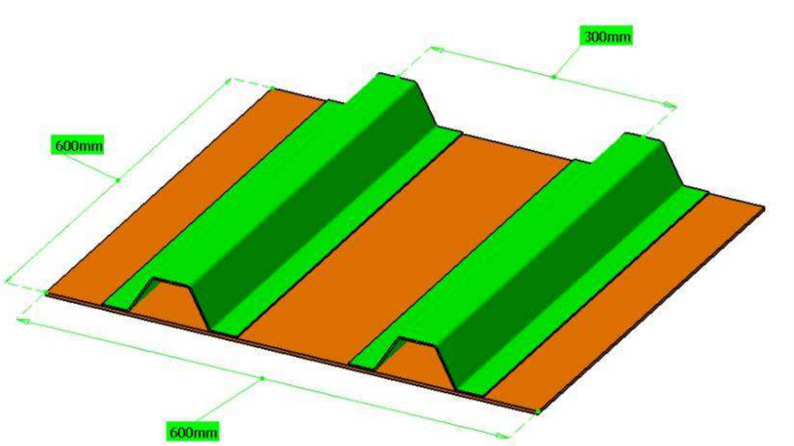

Figure 6: Demonstrator geometric dimensions and general scheme

Both skin and stringer has been manufactured with the same material, Cytec APC2/AS4. PEEK, 1/4´´width UD slit tape, 220 g/m2 and 34% matrix content weigh.

3.1. Manufacturing process

Thermoformed stringers have been manufactured in a plate press. The control parameters of the process have been the pressure, the temperature of the consolidated laminate and the temperature of the mold.

In these processes, a consolidated flat panel was heated up in an infrared chamber over melting temperature. When the consolidated panel reached the stamping temperature, the laminate was transferred into a mould where it was shaped under pressure to obtain omega profile. Afterward, the omega profile was cooled under pressure up to Tg and remove from the tools. The scheme is shown in figure 7.

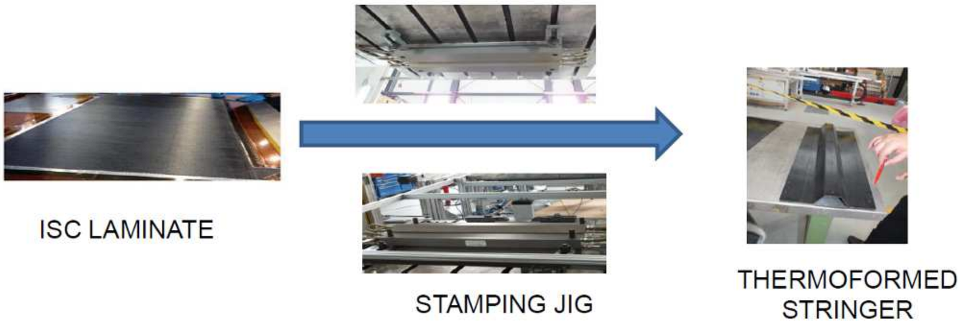

Figure 7: Omega shape manufacturing

In the co-consolidation process by ISC the thermoforming stringers were integrated in the skin during its lamination with the thermoplastic tape placement machine. As a goal to reduce costs it has been developed a new modular tooling concept which assure a perfect adequate fixture of them.

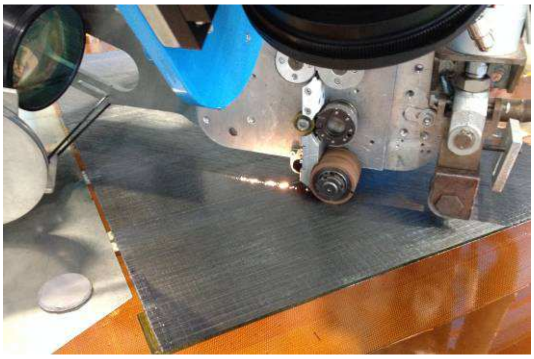

Figure 8: Automated thermoplastic machine

Surface treatments in the stringers is always necessary to benefit the bonding with the deposited material. .To increase the contact in the interface stringer-skin area, a veil of PEEK is necessary to obtain a good result in the co-consolidation process.

Thus, with the automatic layup machine, the flat co-consolidated panel with integrated stringers could be obtained in one step.

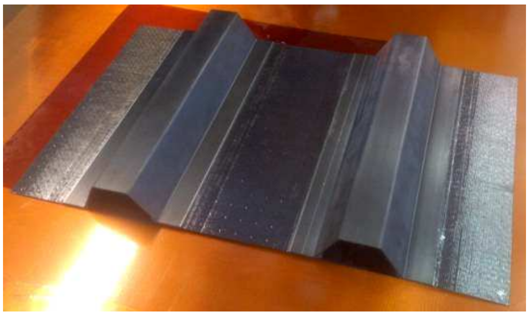

Figure 9: Demonstrator final shape

3.2. Demonstrator NDT analysis

Inspection of the demonstrator has been performed with pulse-echo automatic equipment and guaranteed a good bond in the both stringers-skin join, and porosity with -6dB attenuation

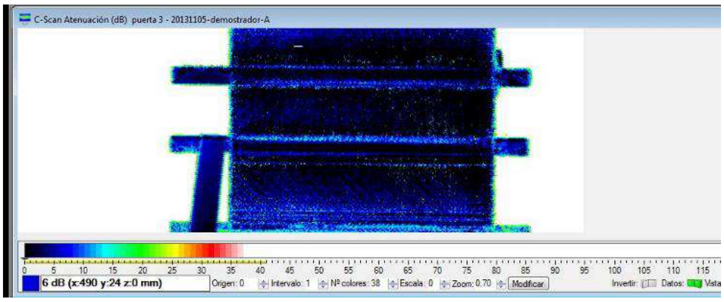

Figure 10: Attenuation C-Scan for Stringer 1

3.3. Environmental assessment

Environmental evaluation has been performed by analyzing the environmental impact of the process and comparing to an established and commonly used composite manufacturing process such as automatic layup and autoclave curing of thermoset-resin-based.

This study concludes that the automatic in-situ consolidation of thermoplastic materials manufacturing process represents an alternative, very beneficial in terms environmental sustainability, to autoclave manufacturing processes (low environmentally optimized), and involve significant advantages in terms of environmental sustainability

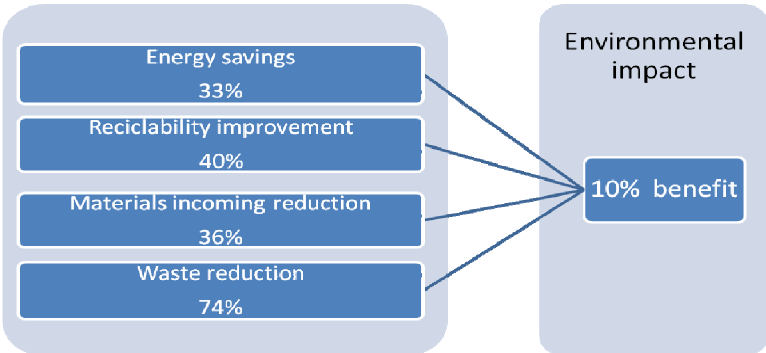

Figure 11: Environmental benefits

In addition, thermoplastics can be remoulded and recycled directly by remelting heating up above a specific temperature, without negatively affecting the material's physical properties. This characteristic allows, by one hand, to increase the lifetime of the product, thanks to the ability to be reprocessed and repaired and of some defective parts, and by other, recycling the end life structure.

4. Conclusion

It has been seen that controlling temperature, time and velocity during the process can be achieved a perfect consolidation and stringers integration.

The combination of laser assisted tape placement and thermoforming enables short cycles times global, integration of the stringer as well as fully automated process

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