INTEGRATED HELICOPTER SIDE SHELLS IN INFUSION TECHNOLOGY

F. Weiland[1], U. Beier[1]

[1]Airbus Helicopters Deutschland GmbH, Industriestrasse 4, D-86609 Donauwörth, Germany
Email: frank.weiland@airbus.com, Web Page: http://www.airbushelicopters.com

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Abstract

An innovative manufacturing routine for shell structures has been developed and demonstrated in the frame of the research project “MAI-Fo”. It combines a VAP-infusion with a joining technology based on the interdiffusion of thermoplastic films with epoxies, the so-called “Film-Inderdiffusion Joining (FIDJ)”. This joining method can overcome drawbacks of state-of-the art joining technologies while enabling strong mechanical joints at least on the niveau of the neat epoxy/fiber laminate. It has been combined with a VAP process to an innovative manufacturing routine applied to realize a semi-monolithic design for an integrated helicopter side shell. Benefits have been identified in terms of weight and cost in comparison to the state-of-the-art, which compromises a prepreg-based sandwich design and autoclave curing.

1. Introduction

Helicopter airframe structures are among the most complex in commercial aerospace applications. This is mainly due to the need for very high function densities, accompanied by a strong demand for high performance-to-weight ratios on the edge of technical feasibility. In combination with the low production rates, technologies based on manual process steps are preferred rather than the extensive use of costly arrangements in automated production facilities. Consequently the manual “honeycomb-prepreg” manufacturing routine is still a competitive technology which even outperforms aluminum based technologies in the perimeter of shell applications. All efforts to tackle this challenge by a simple change to different alternative technologies have failed so far.

However a holistic approach strictly focusing on the elimination of the weaknesses of the state-of-the-art approach while exploiting benefits of new technologies in full scope has been conducted to overcome this long lasting barrier. An initial analysis clearly reveals the fundamental limitations attributed to the “honeycomb-prepreg” manufacturing routine itself, which is the low temperature resistance of the core material and the low achievable degree of integration, especially for load-introductions and additional frame elements with significant out-of-plane dimensions. Based on these premises a demand for efficient monolithic designs and technologies facilitating higher integration grades has been identified. In parallel, standardized substructures, a smart absorption of needed complexities with adequate technologies and last but not least material cost reductions are understood to strongly contribute to the final cost.

The bases of the established solution is an adapted semi-monolithic design, as it directly leads to a higher performance level especially at higher temperatures and where damage tolerant behavior is required. As a secondary effect cost for process control specimens is reduced and it enables to switch from expensive prepreg materials to cost-efficient infusion materials (based on e.g. spread-tow fabrics) and processes like preform-infusion routines (e.g. VAP).

The integration technology “Film Interdiffusion Joining” (FIDJ) is the second approach, as it enables the in-situ joining of complex sub-elements manufactured in a suitable technology without increasing the overall production risk and cost. It is based on the interdiffusion of thermoplastic films into the epoxies during cure which enables a high degree of integration without fasteners.

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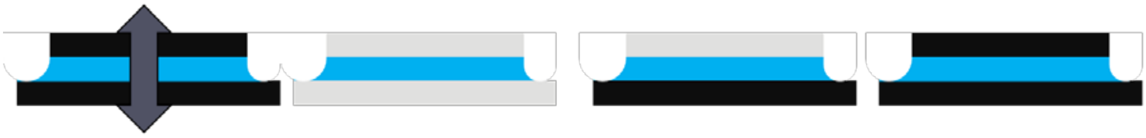
This combined manufacturing approach has been investigated in the frame of research project “MAI-Fo” and successfully applied to a helicopter side shell demonstrator.

1. State of the art joining technologies

State-of-the-art structural joining technologies for FRP in aerospace include riveting, co-curing, co-bonding and secondary bonding.
While riveting is time consuming and adds weight to the structure, co-curing (“one-shot”) can only be applied for low-complexity parts. Co-bonding, i.e. the bonding of a cured part to an uncured part, requires surface treatment of the cured part thus adding costs. Secondary bonding also requires surface treatment which today cannot be realized in a cost effective manner.



Riveting	Co-curing	Co-bonding	Secondary Bonding
two or more already-cured composite parts; mostly shimmed	same cure cycle for adhesive and other resin systems, no already cured part	same cure cycle for adhesive and one resin systems, one already cured part	two or more already-cured composite parts; only curing of the adhesive itself
+ no specific surface treatment needed + manufacturing process can be separated into steps	+ no specific surface treatment needed + no geometric tolerances between joining	+ no geometric tolerances between joining + medium complexity of parts possible	+ high complexity of parts possible + manufacturing process can be separated into steps
- min. part thicknesses **- Cost for drilling** **- Additional weight**	**- only low complexity of parts possible**	**- surface treatment needed on one part**	**- surface treatment needed** **- tolerances between parts to be considered**

Figure 1: Overview state-of-the-art joining technologies for aerospace FRP

Numerous research activities target innovative joining methods that overcome these drawbacks while still comply with certification requirements.

2. „Film Interdiffusion Joining FIDJ“: Scientific Basics

Some thermoplastic materials like PEI and PES are known to be soluble in uncured epoxy resins [1]. During cure of the resin under temperature, an interphase between the epoxy and the thermoplastic forms. The interphase formation mainly depends on involved temperatures and heating rates [2]. The following phase separation during the solidification of the epoxy allows for a mechanically strong bond between the two polymers. Figure 2 shows SEM images of an interphase and illustrates the gradial transition between the material and gives an indication of the interphase thickness (usually between 10 and 50µm).

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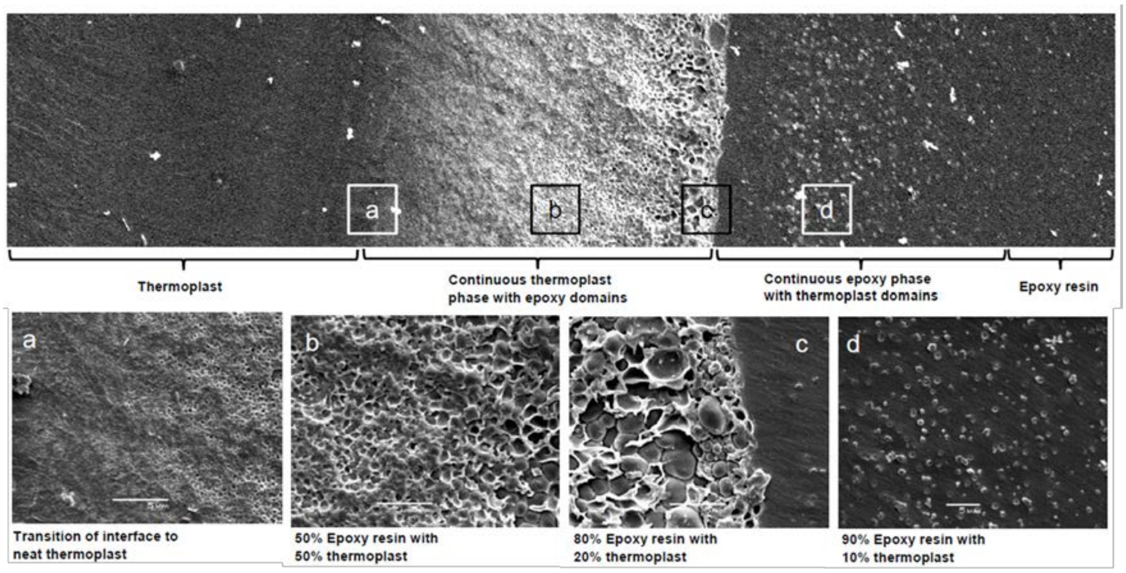

Figure 2: SEM image epoxy-PEI interphase [3]

In the frame of the research project "MAI-Fo", the mechacnical capability of this interface has been characterized. As representative tests, G_{IC} and G_{IIC} values of a standard aerospace epoxy/carbon fiber laminate with and without interlayered PEI film are displayed in the following graph. Significant increase (+188%) has been measured for the strength out-of-plane while in-plane strength is comparable to the reference.

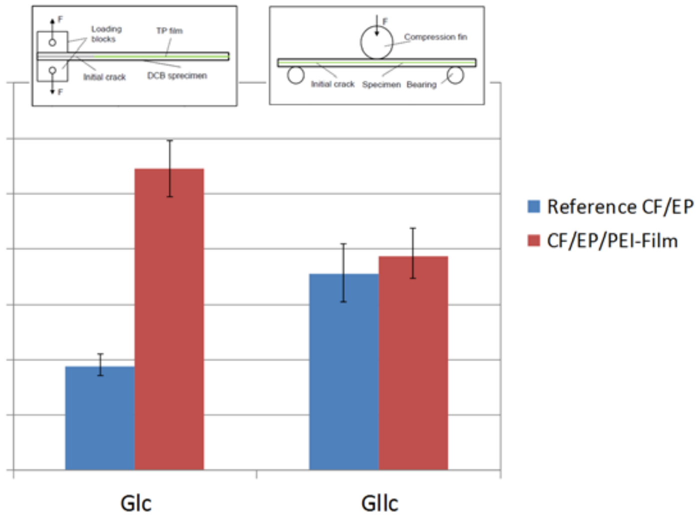

Figure 3: Mechanical performance of standard epoxy-CF laminates with PEI interlayered film

These measurements had been conducted following systematic material selection according to aerospace requirements (media resistance, manufacturing and in-service conditions) and have been accomplished with an extensive test program.

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3. Manufacturing routine

Based on the selected M&P concept, potential process routes could be proposed.
One routine includes the integration of a cured thermoset component with an thermoplastic film on its surface into a dry preform assembly. The following infiltration and cure of the component initiates an interface joint between the components.
This routine enables a prepreg-based pre-cure of selected components (e.g. components of high complexity like brackets) that would significantly increase process risks and tooling cost – followed by placement of these components towards a dry preform. This assembly can subsequently be infiltrated (by RTM, VARI, VAP or other) and cured exploiting the benefits of such infiltration routine (machine and material costs). thus realizing a rivet free, integrated design while avoiding the usual process risks of a “one-shot-approach”.

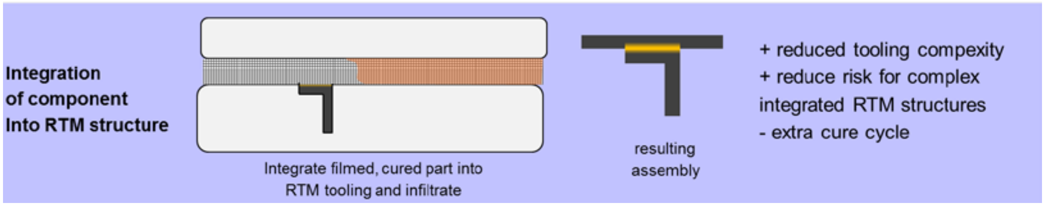

Figure 4: Process routine for filmed components and infilatrion process

4. Side shell demonstrator

This M&P approach has been identified as beneficial for the application to a helicopter side shell based on a semi-monolithic design (i.e. foam-filled beams). Standard for such shells made of CFRP is a rivetless sandwich design.
The semi-monolithic side shell basically consists of a slightly curved skin area plus geometrically more complicated elements such as stringers, frames and equipment pockets.
Following the decribed routine, the concept foresees a precure of the support frames including thermoplastic films on the interface to the skin based on the prepreg-autoclave routine. In a subsequent process step, these stiffeners are placed into a VAP male tooling prior to the layup of the skin from dry fabric.
The following pictures show the design of the side shell and the male VAP tooling.

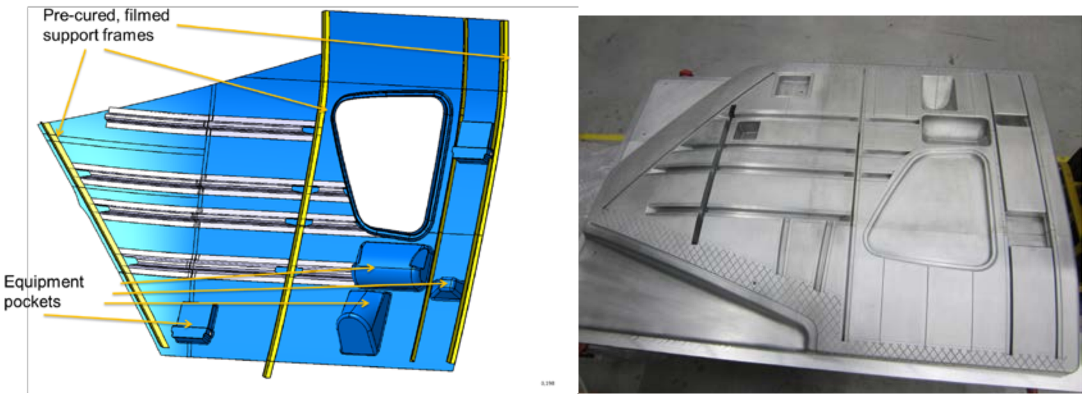

Figure 5: Helicopter side shell demonstrator: semi-monolithic part design and tooling

Expected cost and weight benefit towards the state-of-the-art (i.e. sandwich design and prepreg-autoclave processing) are estimated with a (conservative) minimum of 10 and 5% respectively (see following graphs, Figure 6), whereas primary structure compromises skin, sandwich and stiffeners and secondary structure compromises all kinds of inserts and onserts.

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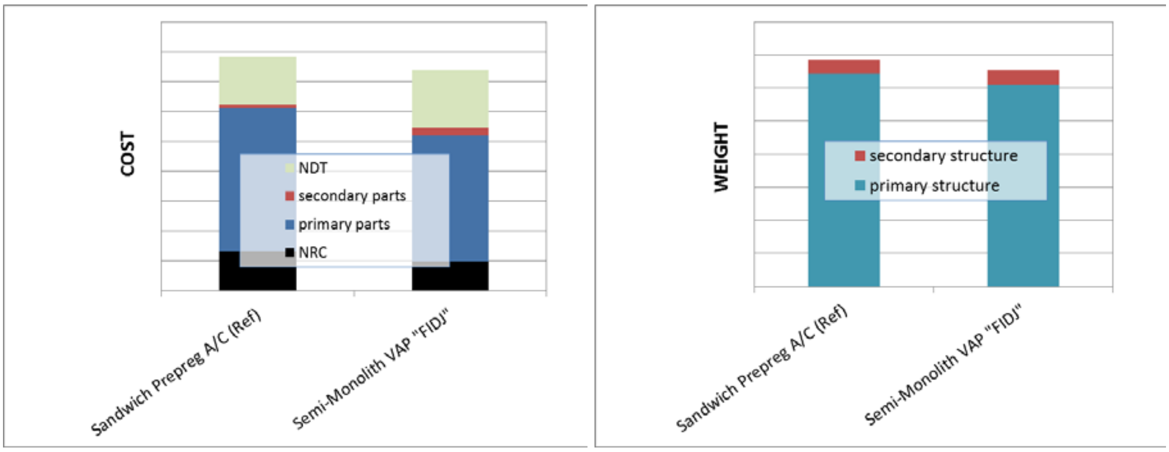

Figure 6: Cost and weight comparison:
each left column: Sandwich design in Prepreg-Autoclave routine
each right column: Semi-monolithic design (foam filled stiffeners) in VAP-FIDJ routine

In the frame of the research project “MAI-Fo”, this approach will be validated (technically and economically).

5. Achknowledgment

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