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"Future Affordable CFRP Helicopter Structures – Advanced Technologies and Adopted Design Methodologies"

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ABSTRACT

This paper presents technologies and design methodologies investigated in several research projects at Eurocopter, with the aim of building affordable CFRP helicopter structures in the future. Several preform joining technologies for infused integrated CFRP structures are under investigation, technologies based on thermoplastic interface layers show high potential from the mechanical and manufacturing side. In parallel, methodologies on how to choose the right technology for integrated structures and on how to select sound architectural concept are developed.

INTRODUCTION

Due to superior weight specific mechanical properties and fatigue behaviour, Carbon Fibre Reinforced Plastics (CFRP) play a major role in Helicopter Airframe structures, which consist today of up to 85% of CFRP.

Current CFRP architectures still show great similarity to metal structures, despite of some parts e.g. Honeycomb Sandwich panels. Actual manufacturing methods for CFRP-helicopter parts are mainly based on prepreg materials with high manual lay-up effort (costly) and its related manufacturing tolerances. The assembly of these cured parts involves complex fitting and shim steps. That is another reason why manufacturing and assembly of these CFRP structures is costly.
Future CFRP helicopter structures have to become more affordable in order to further utilize their advantages compared to metallic structures and to secure the competitiveness of the civil products (helicopters) mainly through weight reduction. Thus new efficient manufacturing technologies and structural concepts are in the spotlight [1].

For future manufacturing of structures, infusion technologies and materials have proven that they can compete with prepreg technologies in terms of mechanical properties and performance. Furthermore, they offer great cost savings.
Aside, it has been demonstrated that great potential for affordable CFRP structures is given in manufacturing of high complex integrated structures aligned with adapted architectures and design [2].

This paper presents a concept on how to select the right technologies for complex integrated helicopter parts. The first methodology describes a way on how to reach integrated structural concepts on a solid base. The second one evaluates integrated CFRP structures based on helicopter specific requirements.

INTEGRATION TECHNOLOGIES

Several technologies/principles are in the spotlight for integral infused CFRP-structures, which are separated in two categories, single or multi step processes. The listed technologies are described below.

Single step curing:

- One Shot Classic
- One Shot with thermoplastic interface
- One Shot with adhesive interface
- One-Shot with mechanical reinforced interface

Multi step curing:

- Co-Bonding
- Co-Bonding with thermoplastic interface
- Co-Bonding with adhesive interface

One Shot Classic

It is the most common way to build infused integral parts by infusing complex fibre architectures, resulting in a reduction of single parts and assembly effort. With the reduction of assembly effort cost savings can be achieved, as well as weight savings through less or no fasteners and no reinforcing pad-ups for joint areas.

But manufacturing large integral parts in this technology implies manufacturing risks. If there is a production failure, it is likely that the whole structure is lost. The risk for production failures is increased through complex toolings and flow fronts.

Additional quality inspection of integral parts can be critical as well as repair and damage tolerance. Current aerospace grade net infusion resins are tending to be brittle while critical structural joints should be toughened to achieve higher damage tolerance.

One Shot with thermoplastic interface

In order to toughen interfaces of an integral structure, one possibility - patented by Eurcopter [3] - is to incorporate a thermoplastic foil in the interfaces. Figure 1 shows a manufacturing sample where the thermoplastic film does not solve in the thermoset resin but gives a good adhesion.

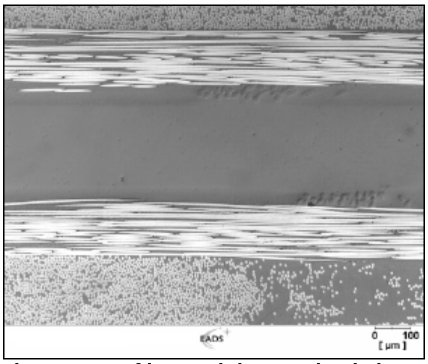

Figure 1: microscopy of integral thermoplastic layer

Besides of toughening the interface, the thermoplastic foil can have other advantages such as separating flow fronts and reducing process risks.

Additionally, it is possible to meld the thermoplastic layer and to replace damaged parts this way. The new part can either be joined with the Co-Bonding process with a thermoplastic interface (described below), or by welding another part with a thermoplastic surface [4]. Still to be proven is how these interfaces can be inspected.

One Shot with adhesive interface

Toughening of the interface can also be achieved by placing an adhesive layer in the interface. Another advantage is, that the replacement of structures can be easier, as the adhesive could be marked with a colour which secures that one part can safely be removed from another through e.g. grinding. Nevertheless, inspection of these joints is still an issue.

One Shot with mechanical reinforced interface

Several methods for 3D reinforced joints such as stitching or Z-pinning are known for preforms. It has been proven that damage tolerance of the reinforced joints can be increased (Figure 2). But in the same time the initial crack initiation, which is relevant for sizing of the structure, is not effected in a remarkable manner and the in plane tension values are affected negatively.

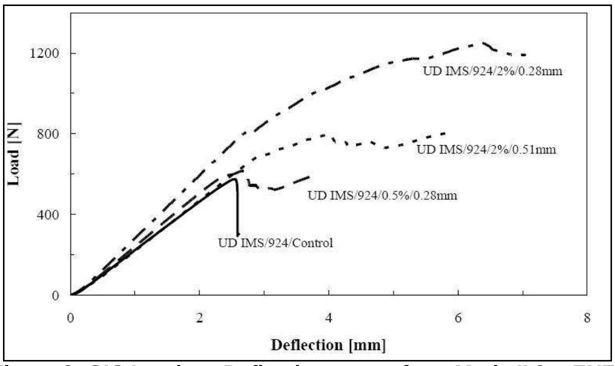

Figure 2: GIC Load vs. Deflection traces from Mode II 3pt ENF tests on UD samples [5]

Also, the insertion of stitches or Z-pins in complex fibre architecture involves high manufacturing effort. That is why these technologies have not further been investigated here.

Co-Bonding Classic

During the Co-Bonding Process, a dry preform is “Co-Infused” to an already cured part. One of the disadvantages of the classic One-Shot process, the high manufacturing risk through complex toolings and flow fronts, can be reduced by separating critical elements. But the mechanical properties of the joints do decrease. The surface preparation, e.g. grinding or plasma activation, of the cured part has to be performed carefully and involves high inspection efforts.

Co-Bonding thermoplastic interface

In order to optimise the mechanical properties and the processing compared to the classical Co-Bonding Process, the first cured part can be equipped with a thermoplastic foil at the surface [4]. In the next process step the next part is co-bonded to this surface The surface treatment of the thermoplastic surface is not that complex, cleaning with alcohol is sufficient. Thus, it simplifies the Co-Bonding steps and optimises the mechanical properties at the same time (Figure 3, Figure 5,). In addition, the thermoplastic sheet at the surface of a component can incorporate several other advantages, like better fire resistance [6].

Co-Bonding with adhesive interface

Strengthening the joint of Co-Bonded structures with an adhesive interface layer is a common method. It is possible to achieve better damage tolerance and higher crack initiation strengths. Nevertheless, complex surface treatment and inspection remains an issue.

TECHNOLOGY INVESTIGATION

The described technologies have been investigated in terms of mechanical performance. For a first characterisation GIC and ILS values were tested at RT . The results are listed in Figure 3, Figure 4 and Figure 5. In order to get a complete picture of these values, hot/wet conditions will be tested as well.

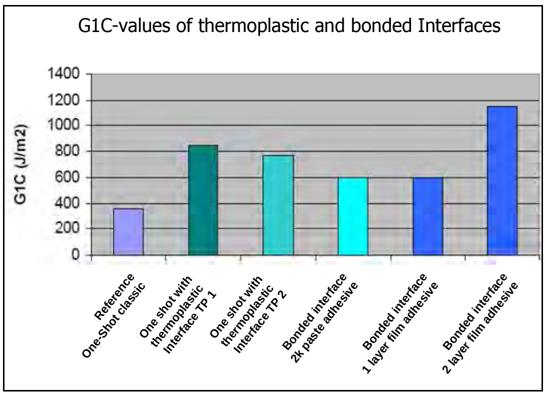

Figure 3: GIC-values of different Technologies, Source: EADS Innovation Works

Optimising the damage tolerance of joints by toughening the interface layer is feasible with different thermoplastic layers and adhesives. Figure 3 shows that the GIC values can be increased significantly with both technologies compared to the one-shot reference.

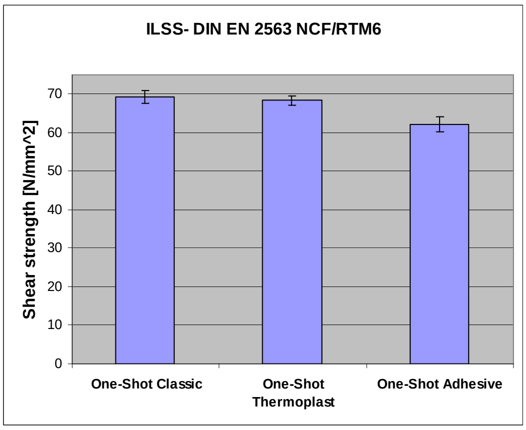

Figure 4: ILSS values for one-shot infused variants

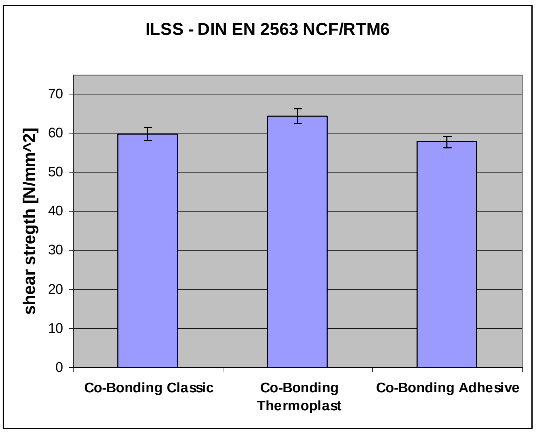

Figure 5: ILSS values for co-bonded variants

In Figure 4 it is visible that the influences on the ILS values are not very high in total, even though lower fibre volume fractions are resulting through the additional interface layers. The one-shot classic reference has the highest value. Due to the specimen design it could not be assumed to get higher values as the reference, even if the interface would have been stronger.

Remarkable is the value for the co-bonding process with thermoplastic interface in Figure 5. It proves that the expected benefits in terms of mechanical properties, compared to the other co-bonding processes are realistic. The adhesive variants could be optimised using another adhesive, the chosen one is designed to ensure good damage tolerance properties.

As shown, each technology has its own advantages and disadvantages. The technologies with thermoplastic interfaces seem to have a high potential for complex integral structures. But their hot/wet performance and the inspectability still have to be proven.
A critical point is that the manufacturing effort for the single parts increases if assembly effort is saved through integrated parts. Thus, the decision of the right degree of integration is complex. Hence, a decision for the technology to be applied has to be made always in combination with structural requirements and has to be made on a case to case basis. That is why a robust methodology is needed to apply the right technology in a complex environment.

DESIGN METHODOLOGY

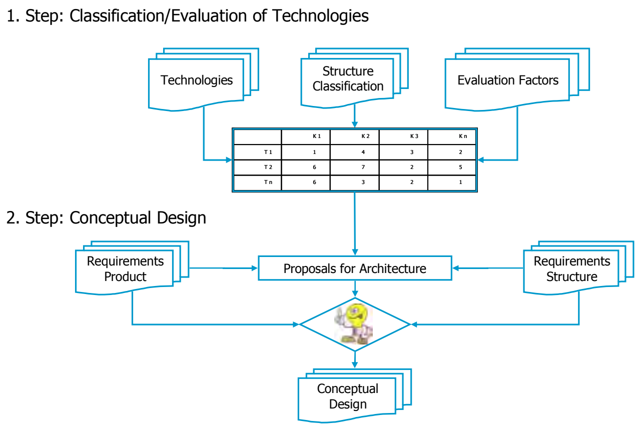

Figure 6: Methodology for the design of structural concepts

The methodology displayed above provides the conceptual designer with proposals for the best fitting technology for each structure/application. Therefore, in a first step, the structure is divided into categories, which are corresponding to properties of the technologies and are representative for helicopter structures. The categories are focused on interfaces as a basis for assembly/integration, which can be:

- Highly loaded
- Moderately loaded
- Curved
- Straight
- …

Each technology is evaluated towards its feasibility for the categorised structures. Then technologies are proposed for the different categories, taking the requirements for the structure and the product into account. It is up to the designer to develop structural concepts on this basis.

DESIGN / TECHNOLOGY EVALUATION

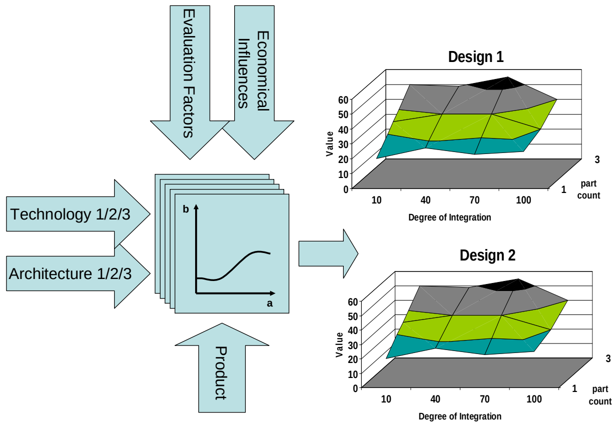

Figure 7: Evaluation of structural concepts

An evaluation methodology for integrated CFRP structures has been developed which takes helicopter specific requirements into account. These are mainly:

- Flexible manufacturing technologies
- Mechanical performance
- Late design changes
- Tolerance management
- Production rate
- Production risk
- Quality assurances
- Repair
- Environmental impact

This evaluation also includes aspects of the whole life cycle of the helicopter:

- Single part manufacturing
- Assembly
- System Integration
- Service
- Maintenance
- Recycling

CONCLUSION

CFRP structures offer advantages (mainly weight reduction and fatigue) compared to metal structures and related designs, but CFRP parts still have to become affordable. The key points to reduce costs are integrated structures and efficient manufacturing technologies.

Adapted design philosophies are essential to utilise the full potential of CFRP-materials. It was shown that preform integration technologies offer a great cost saving potential and supreme performance compared to other integration approaches.

A methodology to assess conceptual designs in early development phases was presented and is available for application.

REFERENCES

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6 Patent application: 2008E01124 DE, “composite structure with functional thermoplastic surface”