# CHALLENGES AND OPPORTUNITIES FOR FUTURE AIRCRAFTS MADE OF CFRP

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## Introduction

Reduction of structural weight of primary constructions in aerospace is an important contribution to decrease development and operating costs. Lower structural weight has also an impact on reduced fuel consumption and therefore also a positive effect on the environment. The use of structures made of CFRP is one promising possibility to reach this goal. By purposeful combination, arrangement and design of the individual components – fibre and matrix – directionality of the material characteristics can be constructed and used in a way which is suitable for the respective application. Furthermore CFRP is characterized by good damping behaviour and by a high specific energy absorption capacity. These additional “degrees of freedom“ lead to a completely new development potential, but also require a more complex and new type of design philosophy as well as inter-disciplinary know-ledge ranging from the design to the production of fibre composite structures. The use of CFRP for primary aerospace structures is already accepted. The part of that material on the whole aircraft structure is continuously increasing. Boeing developed recently the Dreamliner 787 which contains about 50% of CFRP. Airbus is currently designing the Airbus A350, which will contain a similar part of composites. Although, this is a significant step in the aerospace technology, this first airplane generation does not use the full potential of the composite structures. The reason is that there is still a need for research in different areas as stability, effects of defects, structural health monitoring or automation of the manufacturing process. Thus, for the future there are possibilities and challenges in further weight reduction as well in bringing more functionality into the structure. This paper gives to two examples a short overview about the state-of-the-art and demonstrates an outlook in the future design. Example 1 presents results and future activities in the field of stability of composite light weight structures. For such structures as used in aerospace main results of the EU project COCOMAT (Improved MATerial Exploitation at Safe Design of COmposite Airframe Structures by Accurate Simulation of COllapse) and the challenges for the future is given. Example 2 demonstrates the potential and challenges of the TFP technology (Tailored Fibre Placement) which allows a significant weight reduction for composite structures. For the final industrial implementation there are still some challenges which have to be solved.

## Example 1: Stability of Composite Structures

Panels stiffened by stringers and frames as used for aircrafts have usually large reserve capacities in the postbuckling area. For metallics this structural behaviour is traditionally fully exploited, however, not for composites. For composites the structural behaviour was significantly studied in the EU project COCOMAT (2004-2008) which demonstrated that composites also allow exploitation reserve capacities resulting in significantly weight reduction [1,2]. This project aimed at allowing for a structural weight reduction by exploiting considerable reserves in primary fibre composite fuselage structures through an accurate and reliable simulation of postbuckling and collapse. COCOMAT improved existing slow and fast simulation tools and set up design guidelines for stiffened panels taking skin stringer separation and material degradation into account. Reliable fast tools allow for an economic design process, whereas very accurate but necessarily slow tools are required for the final certification. The project results comprise a substantially extended data base on material properties and on collapse of undamaged and pre-damaged structures subjected to static and low cycle loading, degradation models, improved slow and fast computation tools as well as design guidelines. Although, with respect to loads and characterristic dimensions, this project was oriented towards an application in the fields of fuselage structures, the results are transferable to structures from other engineering field as well.

### Example 2: Tailored Fibre placement

Tailored Fibre Placement (TFP) is a textile process for the production of fibre reinforced structures. Using TFP the carbon fibre rovings may be placed on a base material in almost any desired orientation, thus deploying calculated optimum fibre quantities and orientations for optimal performance. In structures the anisotropic material properties are usually not fully exploited. Stress concentration at notches, edges and cut-outs are critical in view of the material failure behaviour in a structure. While in isotropic structures only a shape optimization is possible to reduce local stress concentrations, in orthotropic and composite structures an orientation of the fibres appropriate to the local stress condition can be used as an additional local design variable for strength and stiffness optimization. Main area of application are uniaxial loaded laminate structures with a limited number of load cases. An example is the HTP (Horizontal Tail Plane)-connection beam which was investigated within recent research projects [3]. It was demonstrated that for selected load cases the TFP technology has high potential for weight reduction [7]. Figure 1 shows the optimized fibres which demonstrated larger load carrying capacities. However, in order to be able implementing this technology in the industrial process the following questions need to be investigated.

1: Reliable material properties: Comparing TFP to prepreg, one can assume that TFP exhibits similar stiffness but smaller material strength values. The strengths are reduced due to the increased fibre waviness. In addition, the carbon rovings are slightly damaged by the needle threads during the manufacturing process. This leads locally to spatially varying material properties. The compressive strength can be between 40% and 70% compared to prepreg. Despite the large reduction of the strength values, the TFP technology has still potential in weight reduction. The challenge for the future is not to achieve a most possible value but to guarantee the magnitude in the daily industrial process.

2: Automation of the design process: The optimisation of the fibre directions is performed by means of Finite-Elements. The results are modified directions of the fibres for each finite element. These directions are straight lines which change the direction from element to element. For the manufacturing process, however, smooth lines are needed. The step from the outcome of the numerical optimisation to the real optimised solution need is currently a hand-made process and need to be automated.

3: Certification of the manufacturing: Placing of the rovings in curved lines leads to different results. This manufacturing process needs therefore to be further investigated and certified.

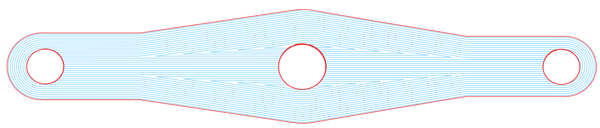

**Fig. 1** Optimised fibres in the HTP-connection beam


### Summary

The use of composite structures aerospace applications has the main advantage of weight reduction comparing to metallic structures. The first airplane generation does not use the full potential of the material as there is still a need for research in the area. This paper gives to the topics Stability and Tailored Fibre Placement an overview about the state-of-the-art and shows an outlook in the future design.



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