

Construction of a Composite Helicopter-Structure at Eurocopter



Key Highlights

Industry
Aerospace

Challenge
Design of a composite tail boom

Altair Solution
Three stage optimization process using the HyperWorks suite to improve performance characteristics

Benefits

- Development time saving
- Design optimization

Introduction

The mass of a helicopter is a crucial cost factor in air traffic. During the lifetime of a helicopter, every superfluous pound of weight costs thousands of Euros. These costs arise due to the additional fuel needed to move the extra mass thus limiting the amount of cargo the helicopter can transport.

To build lighter helicopters, aerospace companies and engineers use lightweight materials such as composites. Compared to the widespread aluminum, these new materials are not only lighter but also offer, thanks to their individually combined material structure, better load and stress characteristics. Not surprisingly, in advanced aerospace engineering today, lightweight composites with excellent stiffness and load

resistance characteristics have become the material of choice. However, the design of composite components is rather complex. The material consists of different layers oriented in various directions. These layers are formed of a matrix of single fiber batches in diverse compositions. Due to the countless possibilities to combine the material, engineers face the challenge of considering many different parameters in their development process, before a component made of composites can be manufactured. To improve the development process of composite components and to define a process that takes into account both material and production related parameters, the industry has started to apply a simulation based approach for the design and optimization of new composite parts.

Composite Optimization at Eurocopter

The Use Case

Eurocopter is a German-French-Spanish company and a business division of EADS. With a market share of 52 % in 2009, the company is the worldwide leader in the helicopter industry. Among other tools, Eurocopter uses Altair's computer aided engineering (CAE) suite HyperWorks, which was applied in the use case described here. In the presented project, a pragmatic approach for the design of CFK (carbon fiber reinforced plastic) components was to be found. As a specific example, the engineers designed a composite tail-boom of a civil helicopter using Altair's optimization solution, OptiStruct. The study included two different approaches:

1. Entirely new design of CFK ply book layout
2. Optimization of an existing CFK ply book assembly

The focus of the project was the optimization of the existing design with the aim to find out how CAE optimization could further improve it. The project was a cooperation of Eurocopter and Altair ProductDesign, Altair's design and engineering consulting division. Eurocopter contributed their aviation expertise, while Altair ProductDesign provided their know-how in optimization technologies. Thus, the required competence

for both disciplines was available at every stage of the project.

New Ply Book Layout Design

For the layout process of the new tailboom design, Altair's standard process for composite components was used, consisting of a three-stage optimization. The first optimization run defined component areas, requiring patches with a defined material orientation. For this, the layer distribution of each element of the CAE model was used as an optimization parameter. The result of this "free-size" optimization

was a design proposal for the layer distribution, showing the optimal shape and thickness of each single patch and providing the numerically ideal design for the given optimization task. However, this proposal is usually not suitable for a direct design implementation, because only discrete thicknesses and patch sizes can be used in the real component. Manufacturing constraints were not considered until the second optimization loop, the "sizing" optimization. After the "free size" optimization, OptiStruct proposes a parametric input deck for the second optimization run delivering the discrete thickness of the patches and the exact number of fiber layers needed.

Subsequently, the proposed process foresees a "shuffle" optimization with a varying sequence of layers.

Since the focus of the overall tailboom project was on the optimization of the existing design, only the "free size" optimization was carried out at this stage of the project.

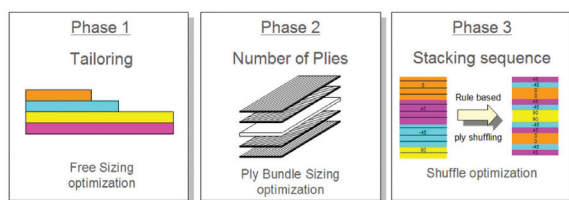
For the "free size" optimization, the component (a part of the tailboom) was divided into monolithic sections and

areas with sandwich tube skin (honeycomb), used to reinforce the structure. This partition was necessary because of pre-defined component areas where honeycomb structure could not be used. The pre-set design parameters allowed

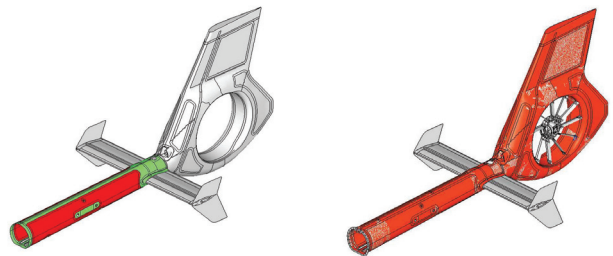
four layers per element with the orientations: 0° , $+45^\circ$, -45° , and 90° . Each single layer consisted of unidirectional material, making sure that the optimization delivered the dominant orientation of the layers. The layer sequence was "smeared" across the component thickness to disregard the lamination of the single layers. This approach ensured that the original layer sequence (starting parameter) would not influence the optimization result and would produce robust end results. In addition to

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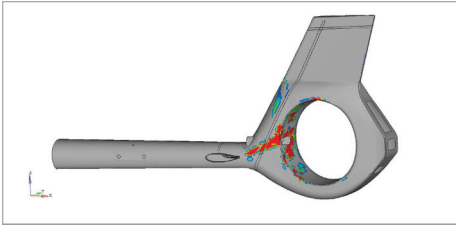
Composite Optimization



Three Phase Optimization Process

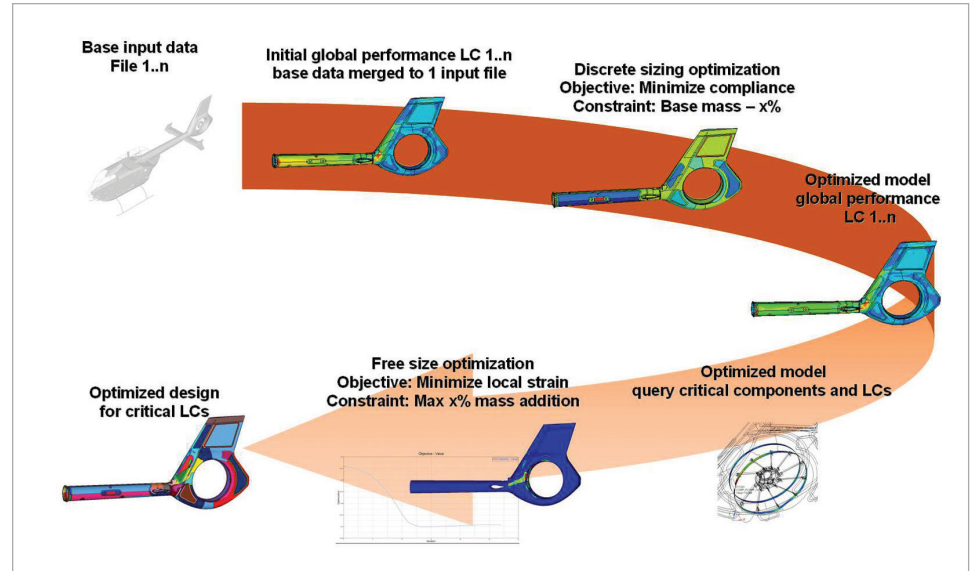


Design areas for the optimization according to the composite type (red = area of honeycomb, green = monolithic areas)



About Eurocopter

The Eurocopter Group is a 100 percent owned subsidiary of EADS (European Aeronautic, Defense and Space Company), one of the three largest aerospace groups in the world. The company develops commercial and military helicopters, and is involved in all European Airbus programs through the development of aircraft doors and fairings.



Proposed development process for the re-design of an existing ply book assembly

symmetry, boundary conditions such as the structural stability of the component against buckling (two buckling load cases) and the overall mass of the tailboom had to be considered. The optimization target was to maximize the average stiffness in all five given load cases.

Following the optimization, one part of the tailboom showed a decreasing layer thickness along the boom towards the rotor. This decreasing thickness was a result of the load distribution on the tailboom, revealing a peak at its connection to the helicopter fuselage. Additionally, the structure around the vertical fin was enforced to better absorb the emerging loads. By this means, the global stiffness could be improved, showing an optimized strain distribution and a reduced displacement at the end of the tailboom with all load cases. In addition, the requested basic conditions (reduction of overall mass of ca. 15% and stability against buckling) were successfully achieved.

The results of the optimization clearly showed that the initial design had a

great potential for improvement. Even with a reduced mass, the performance specifications could be reached and even be outperformed.

Optimization of an existing CFK ply book assembly (re-design)

The second part of the project – the “re-design” of an existing tailboom structure was given more detail. The goal of this investigation was to determine how the existing design could be improved, while performing only minor modifications. Additionally, this type of optimization is very helpful to handle reparation tasks, because the engineer can carry out a target oriented optimization to identify structure areas that need to be reinforced. The optimization methods, “free size” and “sizing” optimization, were used for this part of the project.

Again, the starting point of the development was an existing simulation model, including the CFK material specification. Since

the original design (in particular the patches of each layer) was not subject to change, the engineers skipped the “free size” optimization and started directly with the “sizing” optimization. To avoid thicknesses that could not be realized in the manufacturing process, only discrete layer thickness variations were used during the “sizing” optimization, since these allow only multiples of individual layers to be applied.

To define the structure of the single layer patches of the tailboom, the engineers needed 350 independent design variables. The global boundary conditions of the optimization step were set according to the first process (stability against buckling, reduced mass and symmetry). In contrast to the previously studied “free size” process, the engineers only applied a moderate mass reduction, since the design freedom was clearly limited by the predefined patches. The target function was again set with the maximum average stiffness.

This optimization step resulted in improved global characteristics with the given mass reduction. Compared to the original design, the maximum displacement could be reduced by 30%. While the optimized overall characteristics (such as stability against buckling and maximal displacement) were fine, the results of this optimization showed an area where the mechanical performance quality fell off. The optimized model showed a local area with an increased strain. This was because those areas didn't contribute significantly to the global deformation but have to endure heavy applied local loads. With the chosen setup, these areas were not specifically taken into account. A considerably increased strain occurred in the individual layers at the rotor connection. To improve these local weaknesses, an additional optimization was run, based on the results of the "sizing" optimization. The engineers modeled an additional layer assembly of elements (four layers with the orientations 0°;+45°;-45°, and 90°) covering the entire area of the component, and carried out a "free size" optimization. The existing layers remained unchanged, representing the required "basic stiffness". In this step, only the weight saved in the first "sizing" optimization was subject to be re-distributed. The goal of this optimization was a significant re-investment of the previously saved mass to meet the performance criteria

While keeping the same weight, the two buckling load cases could be improved by more than 10%, the deflection at the end of the tailboom could be improved by more than 35%.

in the critical areas, while not exceeding the mass of the original design. The results of the optimization delivered a thickness distribution of the additional reinforcement layers. The additional layers were then finally applied to the existing layer assembly and an analysis of the optimized construction was carried out.

At the end of the development cycle, the engineers received the following results: while keeping the same weight, the two

buckling load cases could be improved by more than 10%, the deflection at the end of the tailboom could be improved by more than 35%, the maximum strain and stress was similar to

those of the original design and the overall model showed a significantly improved global strain distribution.

Conclusion and outlook

Both approaches, the design of a new and the improvement of an existing ply book assembly for a tailboom, clearly show how CAE optimization and especially the capabilities of HyperWorks can help engineers to optimize a component in a pragmatic approach, taking into account multiple material parameters and boundary conditions. The presented re-design of the ply book assembly offers excellent potential to improve and accelerate development processes. However, the evaluation at

Eurocopter has also shown that the exemplary optimization process does not yet offer an entirely automated solution. Especially the definition of the optimization setup for complex layer assemblies and combination of load cases play a key role in optimizing CFK structures.

CAE tools and their ongoing enhancements for the design and optimization of composite materials provide the engineer with an advanced and powerful tool to evaluate composites and to design a customized target oriented component. New workflow processes and software functions will be tailored to the use of these materials and offer, despite the complexity of the application, a practicable way to broaden the use of lightweight structures in the development.

The close cooperation between Eurocopter and Altair ProductDesign offers great advantages to both companies making sure that all complex challenges in the project are addressed. Eurocopter improves its development processes and is able to rely on the latest technology and development tools, while Altair ProductDesign and Altair receive valuable information on market requirements for their software environment, HyperWorks, which can be implemented and made available to all their customers.

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