

Tailboom Optimization

Eurocopter – EHTC Ludwigsburg – 2009-11-04

Markus Schemat
Team Manager East
Altair Engineering

&

Jörg Löffler
Research & Development
ETVAS – Airframe and Vehicle Integration – Stress
Eurocopter Group



Altair[®]
Product Design

*The shortest distance between
concept and reality*



EC tailboom optimization

Agenda

1. Introduction and model information

1. Introduction and target of investigation
2. Model description

2. Scratch ply design

1. Optimization set up free size optimization
2. Result overview free size

3. Ply redesign process

1. Optimization process
2. Result Overview - redesign process

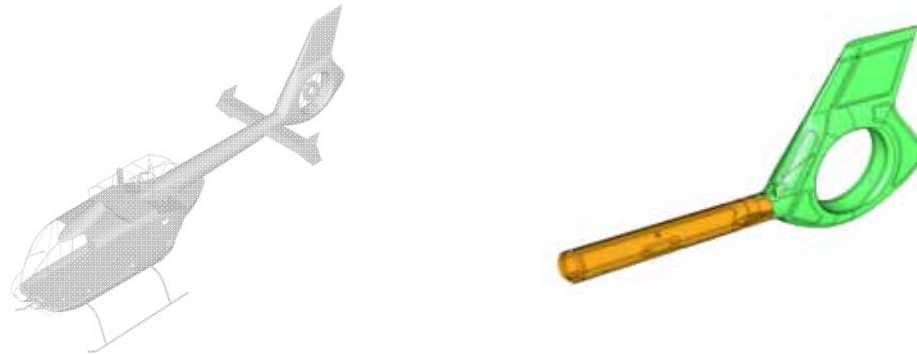
4. Project Summary

1. Overview
2. Outlook

EC tailboom optimization

Introduction

Focus of the optimization is a composite tailboom of a civil helicopter



Aim is to point out improvements with two optimization approaches:

1. Free size optimization (new ply layout design)
2. Redesign process of current design

Investigation of the following properties:

- Global parameters (stiffness & mass)
- Local improvements (Strain, Buckling...)

EC tailboom optimization

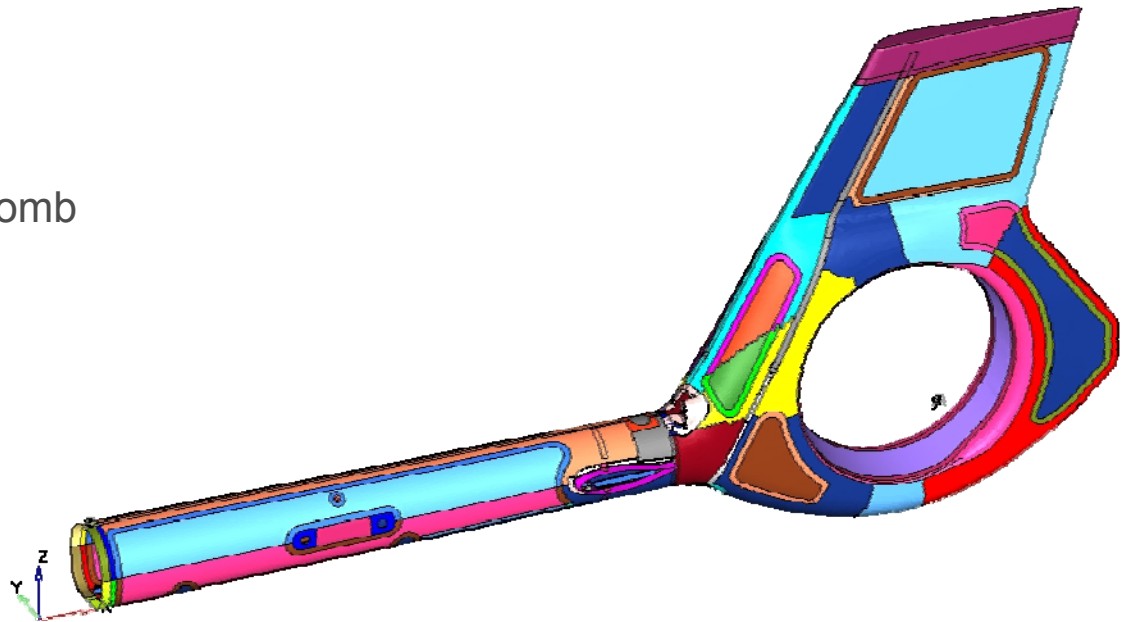
Base model

Baseline model:

- Composite structure
- 92 PCOMP properties
- Up to 12 layers per PCOMP
- Mixed monolithic and honeycomb structure

Load cases:

- 5 base linear static LC
- 2 buckling LC

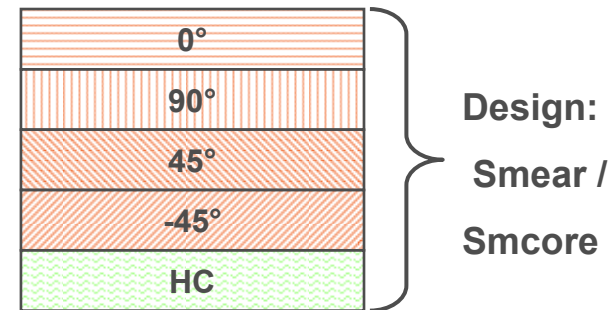


Free size optimization

Optimization set up

Designvars (only boom tube):

- tube skin w/o honeycomb (green)
- tube skin with honeycomb (red)
- Four UD layers [0;90;45;-45]
- Fixed honeycomb thickness (12mm)



Load cases:

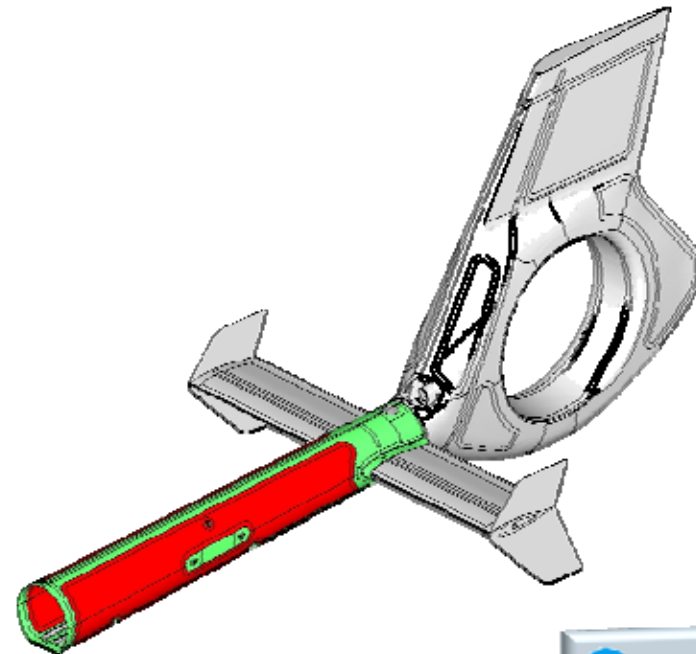
- 5 base linear static LC
- 2 buckling LC

Objective:

- Minimize compliance

Constraint:

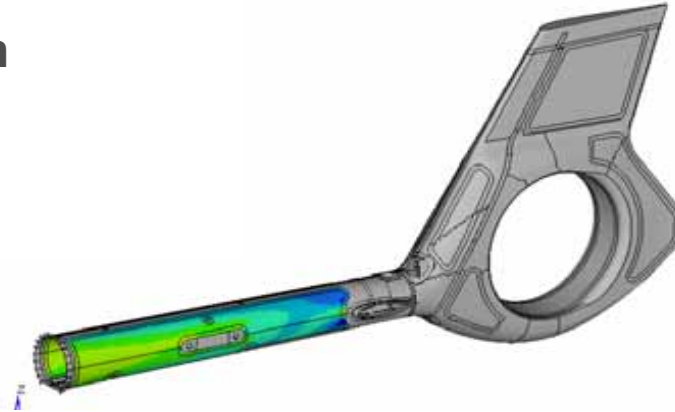
- Tube mass: Base mass -17%
- Symmetric Layout (Y-Axis)
- Buckling > Base



Free size optimization

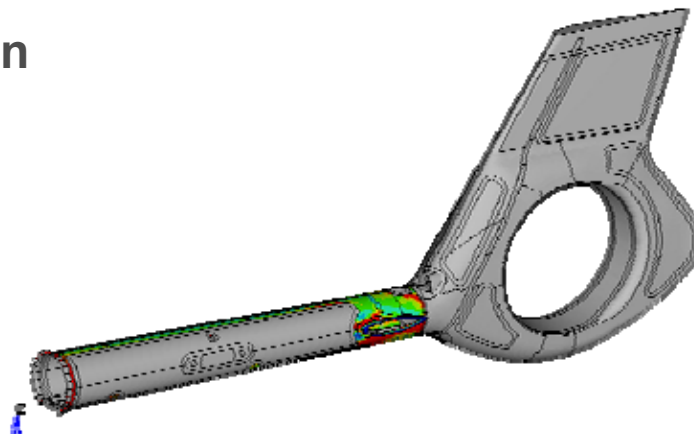
Optimization result - thickness distribution

Sandwich tube skin



Decreasing thickness to the tail is taking „bending behavior“ into account

Monolithic tube skin

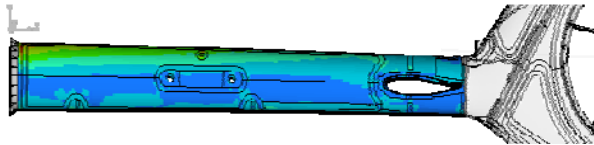


Stiffening structure is created in areas of load influence (vertical fin & cell structure)

Free size optimization

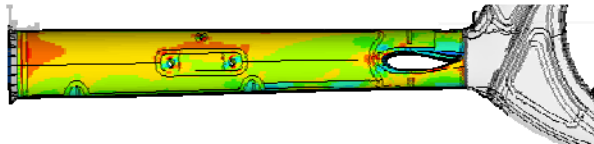
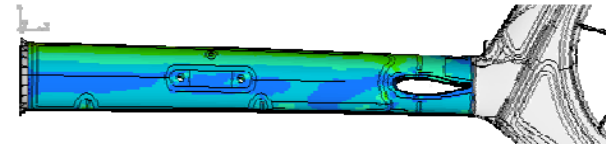
Result overview – composite strains

Base design

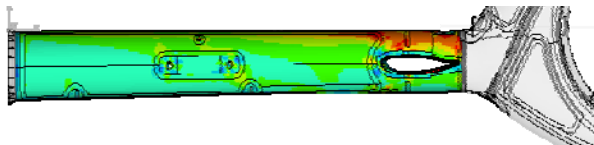


LC1
Ground

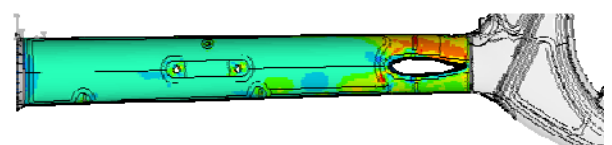
Free size optimization design



LC2
Surface Load #1



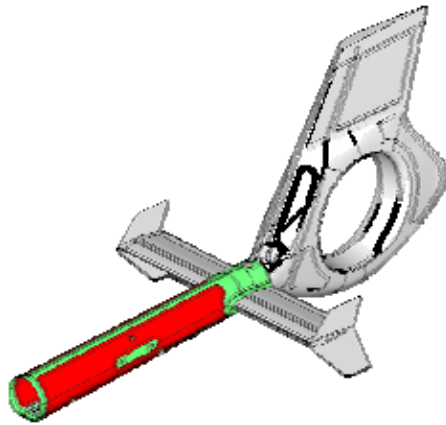
LC3
Surface Load #2



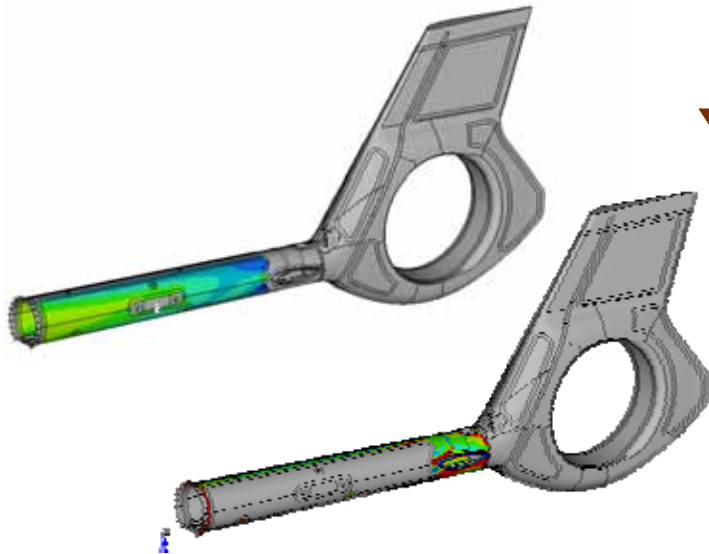
**Huge improvement in global strain distribution
& Reduction of maximum strain peaks**

Free size optimization

Result summary



Free Size



Absolute mass tailboom: **-17%**

Average (LC1..5) tip displ: **-37%**

Average (LC1..5) max strain: **-1,1%**

Average (LC1..5) max stress: **-3,0%**

Buckling constraints feasible

Highly improved global strain distribution

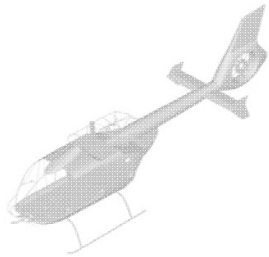
Further steps:

Translation of the free size result to a discrete ply design (not part of this investigation)

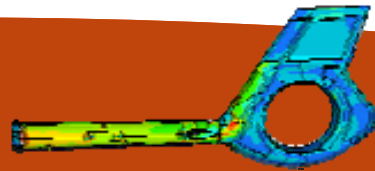
Redesign process

Process for ply redesign

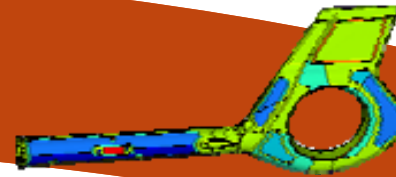
Base input data
File 1..n



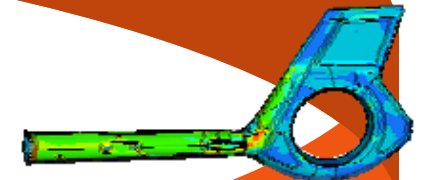
Initial global performance LC 1..n
base data merged to 1 input file



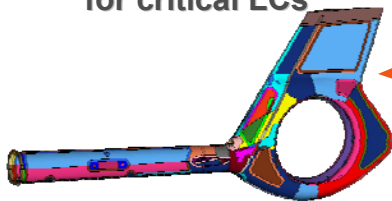
Discrete sizing optimization
Objective: Minimize compliance
Constraint: Base mass - x%



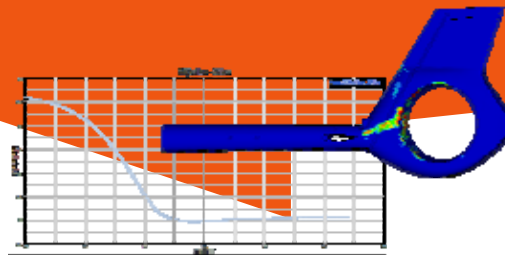
Optimized model
global performance
LC 1..n



Optimized design
for critical LCs



Free size optimization
Objective: Minimize local strain
Constraint: Max x% mass addition



Optimized model
query critical components and LCs



Redesign process

Optimization set up – sizing (global performance)

Designvars:

- Discrete thickness variation
- # of user-defined sizing design variables :
377 (definition on next slide)

Load cases:

- 5 base linear static LC
- 2 buckling LC (Ground & CFD)

Objective:

- Minimize tailboom compliance

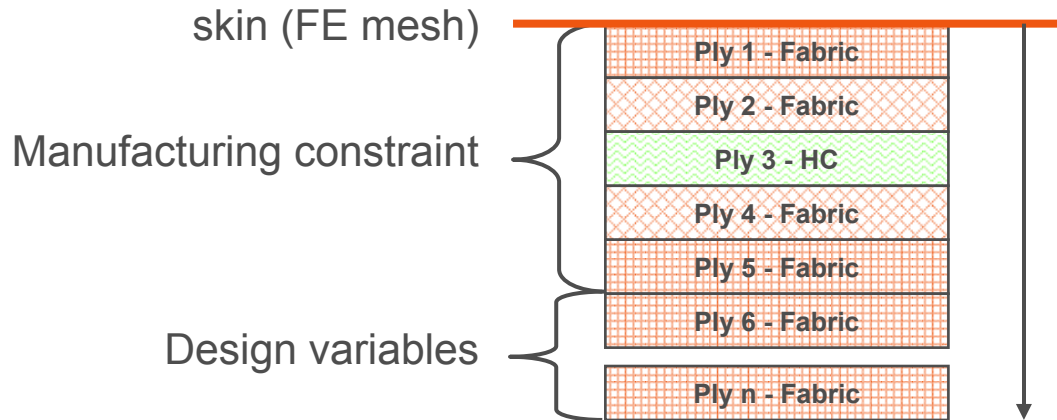
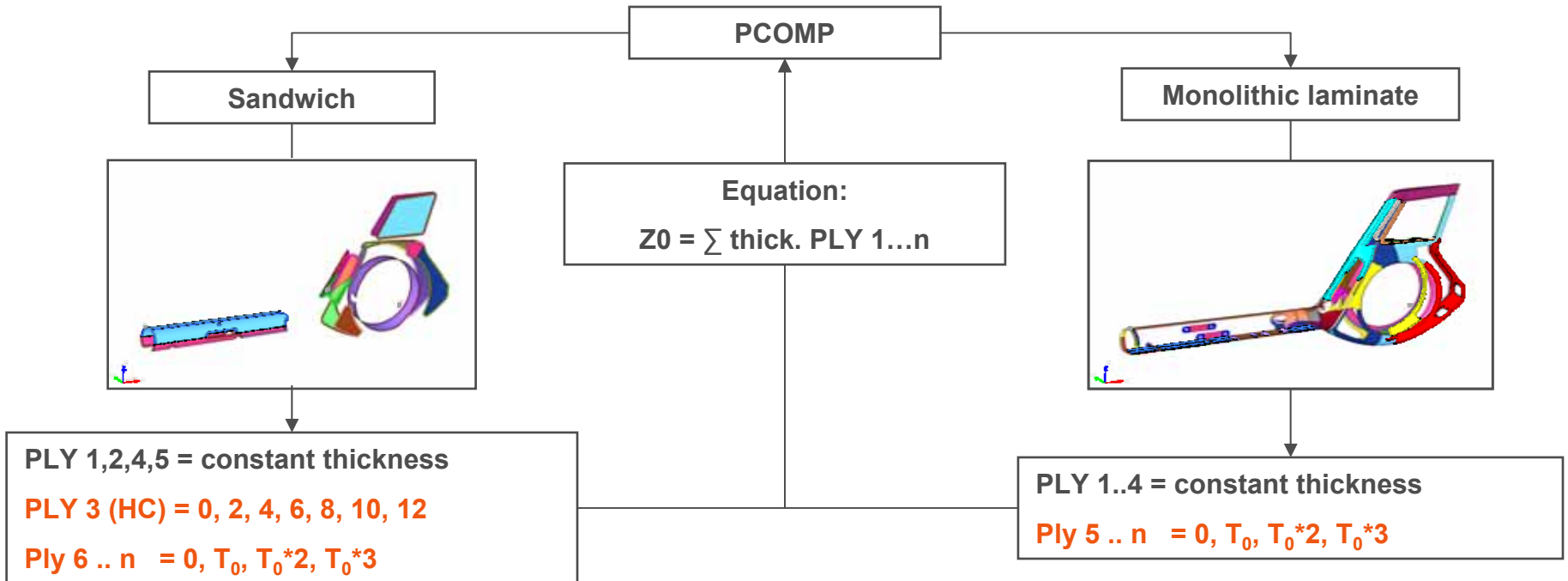
Constraint:

- Mass: $92\% \text{ base} < m < 98\% \text{ base}$
- Buckling factor > 1.8



Redesign process - sizing optimization

Optimization set up – design variable definition

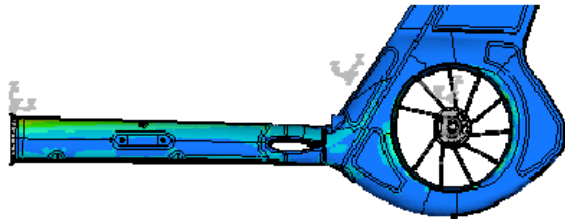


$$Z0 = \sum \text{thick. PLY } 1...n$$

Redesign process - sizing optimization

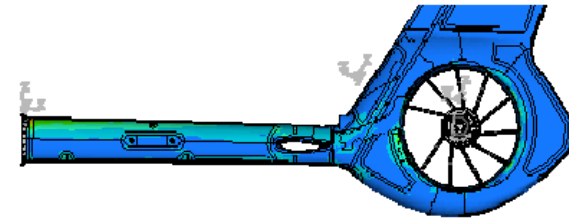
Result overview – composite strains sizing

Base design

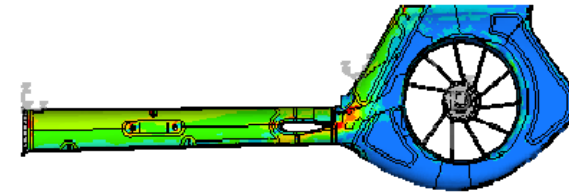
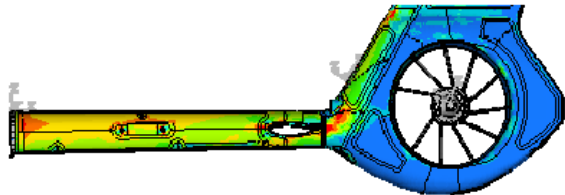


LC1
Ground

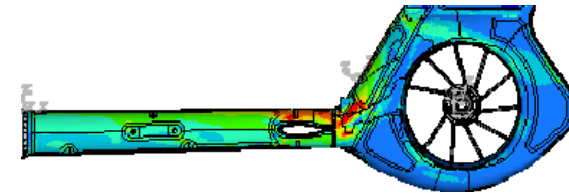
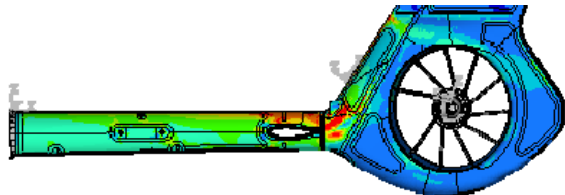
Size optimization design



LC2
Surface Load #1



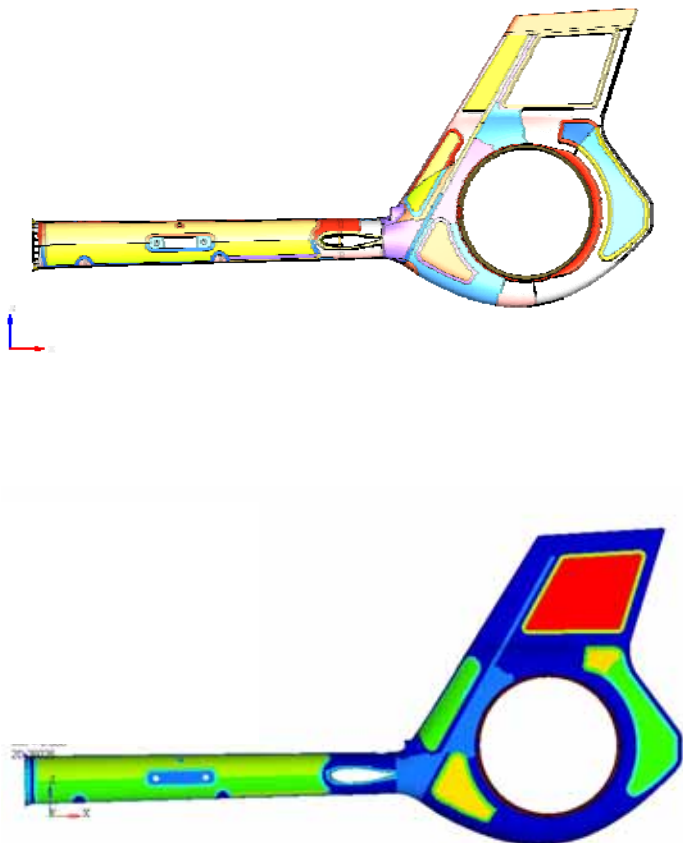
LC3
Surface Load #2



Improvement in global strain distribution
Vs. Increase of local maximum

Redesign process - sizing optimization

Result summary – size



Mass tailboom: - 2.2 %

Buckling LC1 (Mode 1): +40%

Buckling LC5 (Mode 1): +6%

Average (LC1..5) Tip Displ: -35%

Average (LC1..5) Max Strain: +1,7%

Average (LC1..5) Max Stress: 0,0%

Strain change in particular region: +31%

Improved strain distribution

Redesign process – free size optimization

Optimization set up – free size (local performance)

Designvars:

- Tailboom skin (red)
- Four UD layers [0;90;45;-45]

Load cases:

- 1 critical linear static LC

Responses:

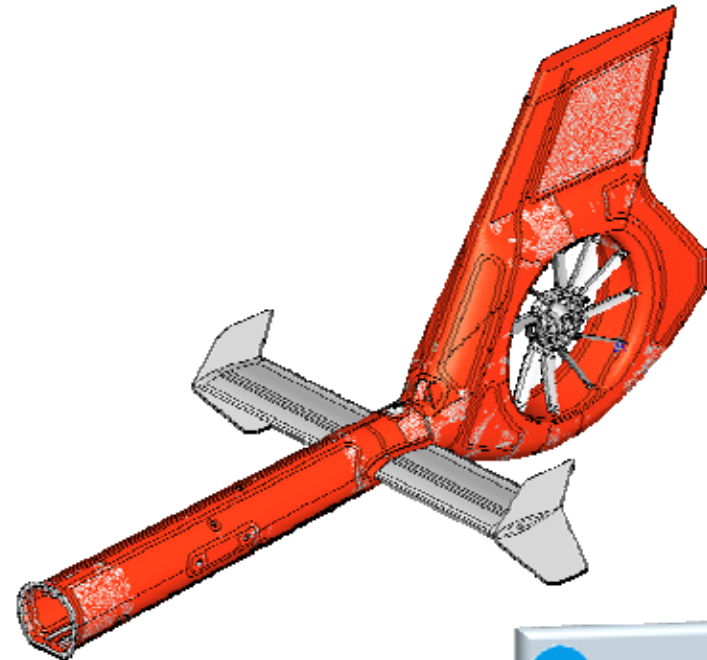
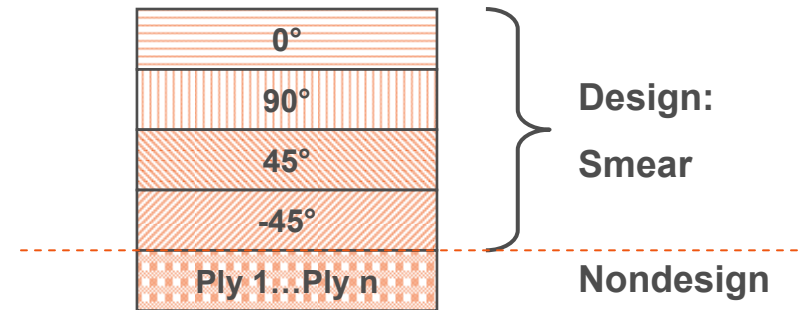
- Added mass
- Composite strains in critical comp

Objective:

- Minimize max strains

Constraint:

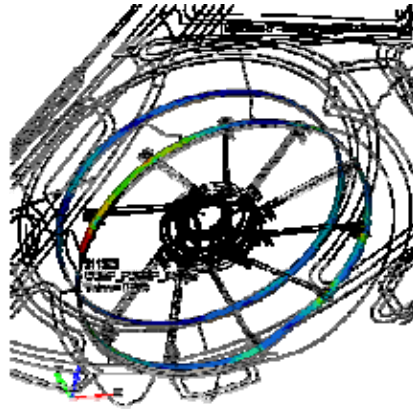
- Max additional Mass +2%



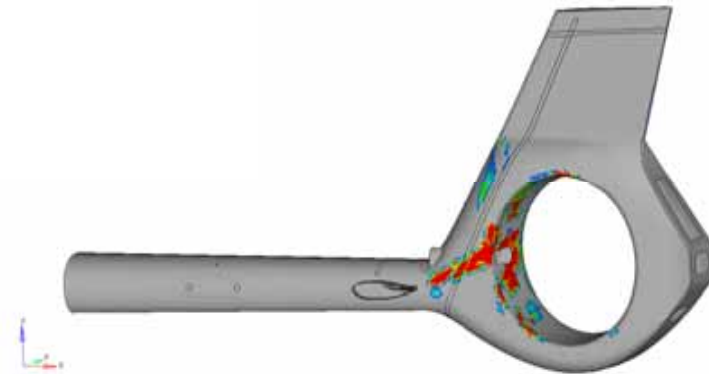
Redesign process – free size optimization

Result overview – free size (local performance)

Critical component:

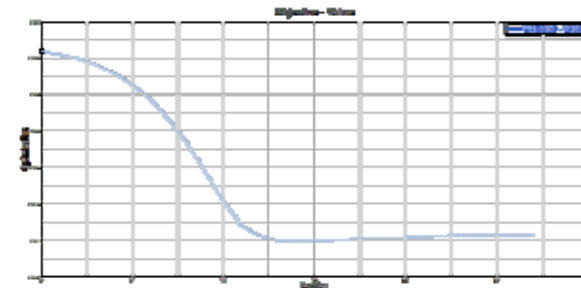


Additional material from free size:



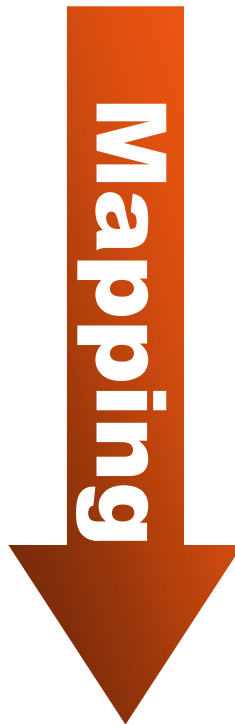
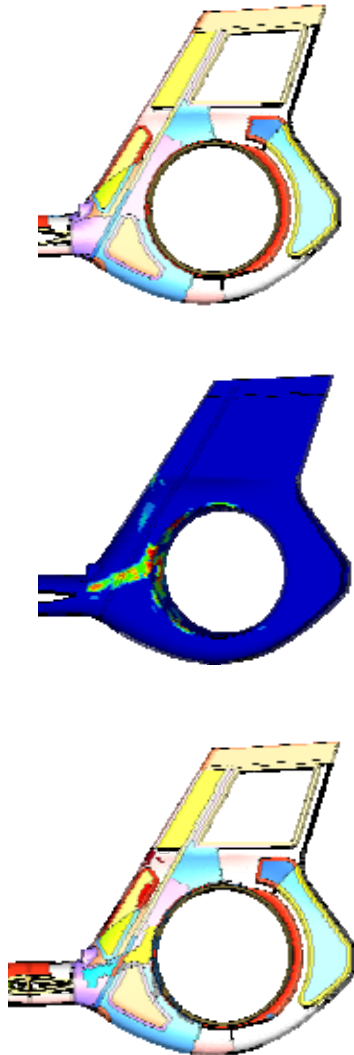
Objective:

Reduction of max stain in critical component by ~35% compared to the base model



Redesign process – mapping

Mapping of free size results to current FE structure



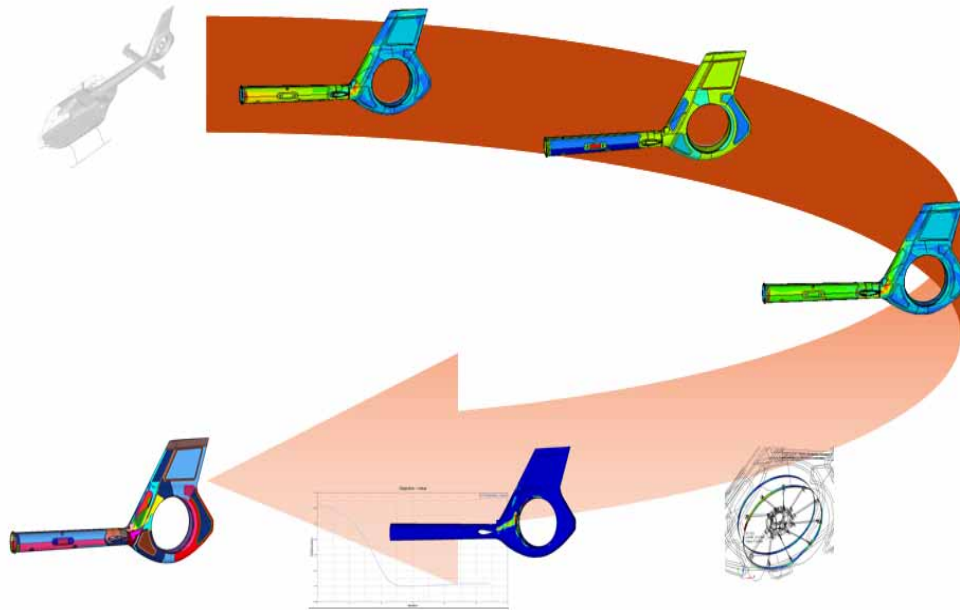
Thickness distribution is mapped to original PCOMP mesh for final analysis

The mapping is currently done manually with additional plies of similar thickness (simplification).

Final mass: ~ Base model mass

Redesign process

Result summary – redesign process



Absolute Mass: ~ 0%

Buckling LC1 (Mode 1): **+56%**

Buckling LC5 (Mode 1): **+12%**

Average (LC1..5) Tip Displ: **-36%**

Average (LC1..5) Max Strain: 0,0%

Average (LC1..5) Max Stress: **-1,0%**

Strain in critical comp: **-35%**

Improved strain distribution

EC tailboom optimization

Conclusion

Summary for the two discussed approaches

1. Free Size:

- a. Best approach for a general ply setup starting from scratch:
 - a. 17% Mass Reduction
 - b. 37% Reduction in average tip displacement
 - c. Homogeneous stress/strain distribution
- b. Currently only global properties are taken into account.
- c. A discrete design needs to be investigated (sizing and shuffling)

2. Redesign Process:

- a. Good approach for ply redesign:
 - a. Mass equal to base mass
 - b. 36% Reduction in average tip displacement
 - c. Up to 56 % increase in buckling factors
 - d. Up to 35 % reduction in local strain strains
- b. Semi-automatic approach to investigate material placement (repair & payload)
- c. Global and local effects are taken into account

EC tailboom optimization

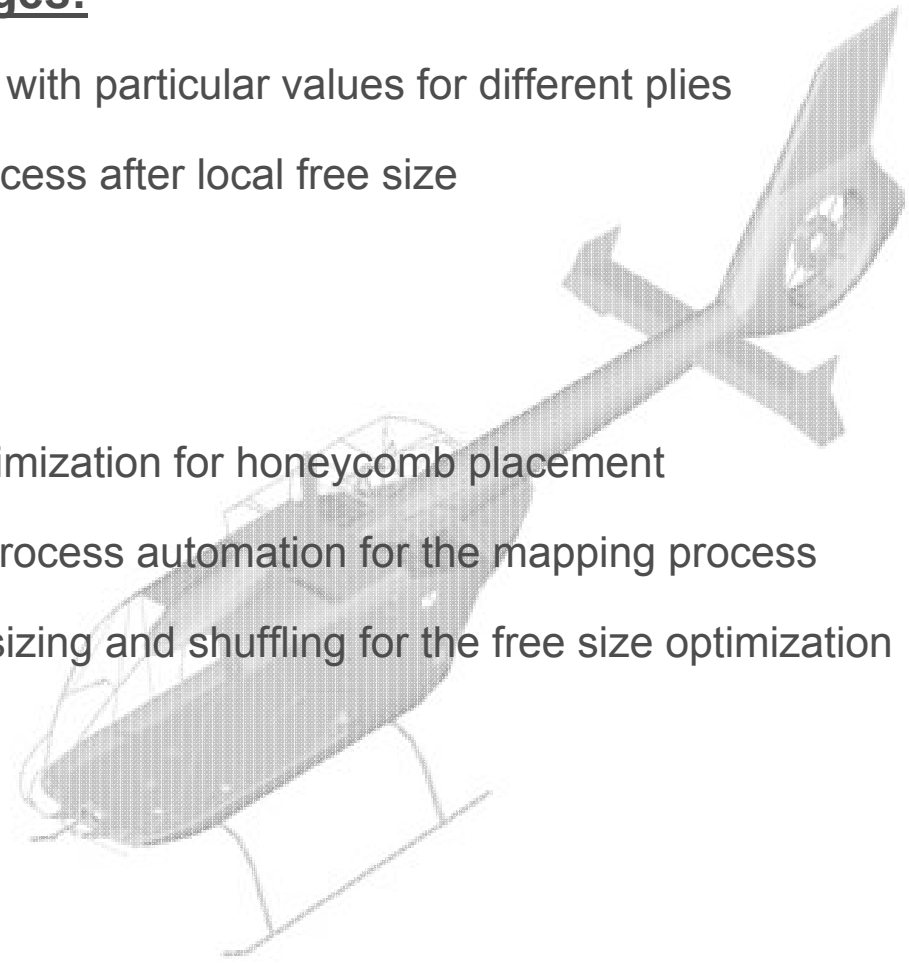
Main challenges & outlook

Main challenges:

- a.) Sizing setup with particular values for different plies
- b.) Mapping process after local free size

Outlook:

- a.) Free size optimization for honeycomb placement
- b.) Inclusion of process automation for the mapping process
- c.) Subsequent sizing and shuffling for the free size optimization



EC tailboom optimization

Questions

Thank you for your attention!

Questions?

