Optimization of the CFRP-boom of a sailing dinghy

11. Weimarer Optimierungs- und Stochastiktage
Knowledge and experience of our employees

Planning and conception

Design and development

Calculation and simulation

Implementation

Knowledge and experience of our employees
Overview - Topics

Introduction:
Sailing, functions and requirements of a boom

Properties of composites:
Influence of the parameters

Design optimization with optiSlang:
Sensitivity analysis, optimization and robustness evaluation

Phases of a composite project:
Integration of the optimization
Boat class International 14

14 foot = 4.27 meter

up to 45 km/h
Boat class International 14

Sailing load
Pusher
Mast
Gooseneck
Boom
Requirements of a boom

- High stiffness
- Low weight
- Sufficient strength
- Low manufacturing and material costs
- UV-resistant
- Resistant to sea water

Goal: Optimization of the composite
Material properties depend on the fiber angle
Properties of composites

Fiber angle $\alpha$ vs. Stiffness [GPa] vs. Number of plies

Countless number of combinations possible

Stacking sequence examples:

- CFRP with IMS fiber
- CFRP with HTS fiber
- Kevlar
- Aluminum
- Steel

Specific stiffness
Project progression in ANSYS Workbench

1: Geometry

2: Meshing

3: Laminate design

4: Load step

5: Results
Design optimization process

Parameter selection

Sensitivity analysis

Checking the Coefficient of Prognosis (CoP)

CoP > 80%
Optimization through Meta-Model of Optimal Prognosis (MoP)

CoP < 80%
Optimization through FE model

Validation

Robustness evaluation

Robust

Not robust

Optimized robust design

Modifications necessary

optiSLang inside ANSYS Workbench
Parameter selection

Sensitivity analysis

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Robustness evaluation

Robust
- Optimized robust design

Not robust
- Modifications necessary
Parameter selection – Input

Before: 43 Input parameter

Material selection

0°-plies in the chord

Constant foam thickness

Production-related stacking sequence

Parameter dependencies

After: 12 Input parameter
Parameter selection – Output

High stiffness

Low weight

Low manufacturing and material costs

Sufficient strength

UV-resistant

Resistant to sea water
Parameter selection – Output

- High stiffness
- Deflection
- Low weight
- Weight-ACP
- Sufficient strength
- Reserve factor for areas
- Low manufacturing and material costs
- Weight-ACP
- UV-resistant
- Resistant to sea water
Parameter set controls project
Sensitivity analysis

Parameter selection

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Sensitivity analysis with optiSlang

Goal: Get an indication of the sensitivity of the parameters

1: Design of Experiments

2: Related model

3: Correlation of parameters
Checking the CoP

Parameter selection

Sensitivity analysis

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Optimization through FE model

Robustness evaluation

Not robust

Modifications necessary

CoP rates the prediction quality of the meta models
Optimization

Parameter selection → Sensitivity analysis → Checking the Coefficient of Prognosis (CoP)

CoP > 80% → Optimization through Meta-Model of Optimal Prognosis (MoP)

CoP < 80% → Optimization through FE model → Modifications necessary

Validation

Robustness evaluation

Robust → Optimized robust design

Not robust
Optimization goals

- High stiffness
- Deflection ≤11 mm
- Low weight
- Weight-ACP Minimize
- Sufficient strength
- Reserve factor for areas RF > 2, RF > 2.5
- Low manufacturing and material costs
- UV-resistant
- Resistant to sea water
1: Selection of the optimization algorithm

2: Selection of the goals, start design and optimization properties

3: Best design recommendation and validation
Robustness evaluation

Parameter selection

Sensitivity analysis

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Optimization through FE model

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Robustness evaluation

Robust

Not robust

Optimized robust design

Modifications necessary
Robustness evaluation

How does the design react to variance?

Types of variances

- Variance due to manufacturing
- Variance of material properties
- Variance due to the force direction
Robustness evaluation with optiSlang

1: Normal distribution of the parameters

2: Related model

3: Robustness of the design

Is the design robust?

07.11.2014
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Robustness evaluation

Parameter selection

Sensitivity analysis

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CoP > 80%

Optimization through Meta-Model of Optimal Prognosis (MoP)

CoP < 80%

Optimization through FE model

Validation

Robustness evaluation

Robust

Optimized robust design

Not robust

Modifications necessary

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Optimization results

- ≤11 mm
- Minimize RF > 2
- RF > 2
- Low weight
- Sufficient strength
- High stiffness
- Low manufacturing and material costs

- Weight - ACP
- Deflection - reserve factor for areas
- Minimize UV-resistant
- Resistant to sea water

Optimization results: 07.11.2014

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Comparison

Initial state

2,50 kg

Optimized laminate

2,05 kg

With equal or better mechanical properties

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Optimization results

- High stiffness
- Deflection: Reduced
- Low weight: Reduced
- Weight-ACP
- Sufficient strength
- Reserve factor for areas: Successful
- Low manufacturing and material costs
- Slow weight reduction while showing compliance to the requirements
- UV-resistant
- Resistant to sea water

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Phases of a composite project

- **Initial phase**
  - Design concept
  - Production planning
  - Project planning
  - Material selection

- **Design phase**
  - Design study
    - CAD
    - FEM
    - Optimization

- **Implementation phase**
  - Mold & prototype construction
  - Part testing
  - Start of production
  - Certification

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Significant reduction of iteration steps save time and money

Good part quality due to composite know-how and use of optimization tools