Conceptual optimal design of jackets

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Conceptual optimal design of jackets

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Figure 1: A jacket in its natural environment.

Motivation
Conceptual design describes the jacket in rough terms [1], such as height, width, and number of legs. This study investigates the influence of leg distance on optimized jacket mass.

Model & Software
In the research project ABYSS, a Timoshenko beam finite element software, JADOP, is developed for structural optimization of jackets. Main features of JADOP are
- Analytic sensitivities
- Parametric jacket topology
- Realistic wind and wave loads
- Fatigue post processing
- Stress concentration factors
- Advanced optimization

Optimization problem
Minimize the mass of a jacket, subject to fatigue constraints:

\[
\begin{align*}
\text{minimize} & \quad f(x) \quad \text{Objective (mass)} \\
\text{subject to} & \quad K(x)u - \Delta P = 0 \quad \text{State equation} \\
& \quad \sigma \leq \Delta \sigma(x) \leq \overline{\sigma} \quad \text{Fatigue (stress)} \\
& \quad \lambda \leq \lambda_i(x) \leq \overline{\lambda} \quad \text{Frequency} \\
& \quad x \leq x_i \leq \overline{x} \quad \text{Design variables} \\
& \quad u \leq u_i \leq \overline{u} \quad \text{State variables}
\end{align*}
\]

where \( x \) describes all the cross sections in the jacket, and \( \Delta \sigma(x) \leq \overline{\sigma} \) is a fatigue equivalent stress constraint.

Structural optimization can explore a large design space (400 jackets) in a short time (2 hours), and thus lead to better conceptual jacket designs.

The influence of leg distance on jacket mass
400 conceptual jacket designs with small changes in the top and bottom leg distances are created and optimized in JADOP. Figure 2 and 3 shows two of them. Figure 4 shows the trends for mass and frequency.

Figure 2: The inwind reference jacket has a bottom and top leg distance of 34 and 14 meters, marked with a blue circle in Figure 5.

Figure 3: The new conceptual jacket has bottom and top leg distance of 28 and 19 meters, marked with a red star in Figure 5.

Figure 4: Three contour plots showing how the leg distance influences the optimal design of the support structure. Note how larger leg distance really influences the jacket mass, while frequency is almost unchanged. The black line indicates jackets where the extended legs would meet at the tower top.

References