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Design optimization of jacket structures for mass production

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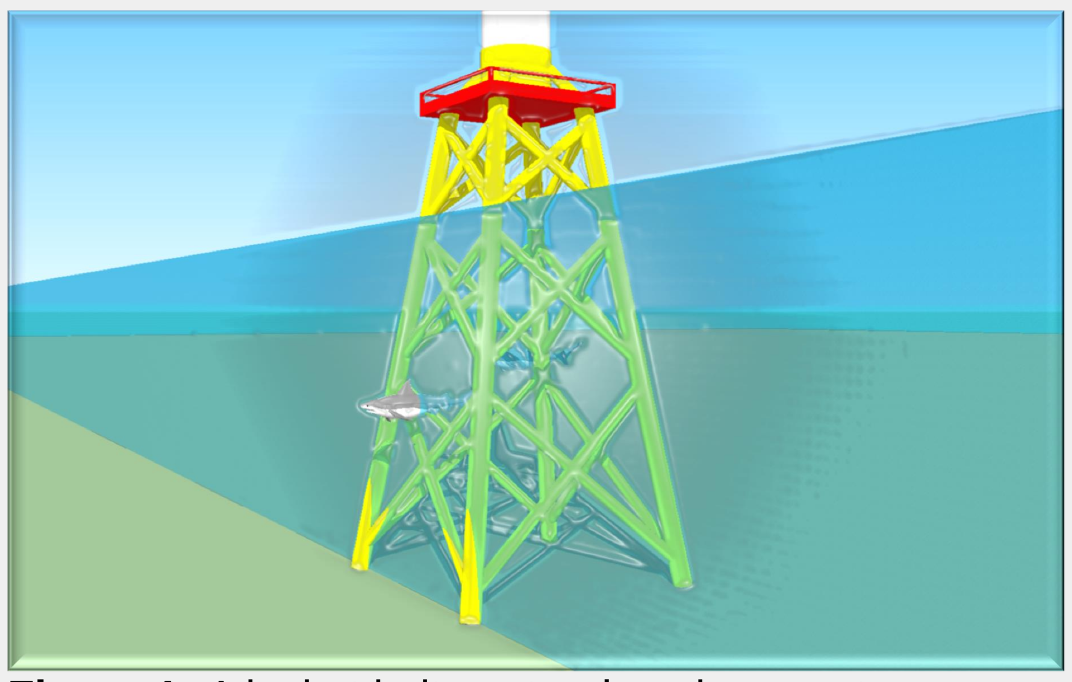

Figure 1: A jacket in its natural environment.

Summary

This work includes a model and method for very fast preliminary design of jackets. Results indicate that the method works well, and current research aims to improve the model.

Jacket model

A jacket model is developed in Matlab for the purpose of design optimization, as part of the research project ABYSS

- *Analytic design sensitivities* are the main motivation for an in-house FE-software. With this information, the design can be optimized using gradient-based methods.
- *Timoshenko beam elements* are chosen, as they are great for frame analysis, keeps the problem size small, and the meshing simple.
- Structural response includes *stress* and *natural frequencies*.

Problem formulation

The aim is to minimize the mass of a jacket, subject to some constraints:

$$
\begin{array}{lll}
\underset{x \in R^{ne},\ u \in R^{nd}}{\text{minimize}} & f(x) & \textit{Objective} \\
\text{subject to} & \mathbf{K}(x)u - P = 0 & \textit{State equation} \\
 & \underline{\sigma} \le \sigma(x) \le \overline{\sigma} & \textit{Stress} \\
 & \underline{\lambda} \le \lambda(x) \le \overline{\lambda} & \textit{Frequency} \\
 & \underline{x} \le x \le \overline{x} & \textit{Design variables} \\
 & \underline{u} \le u \le \overline{u} & \textit{State variables}
\end{array}
$$

Let the diameter and thickness of the members in the jacket be the design variables $\boldsymbol{x}$, and let the displacement vector $\boldsymbol{u}$ be the state variables. We constrain the state variables to satisfy the state equation, and impose bounds on variables and constraints.

Very fast preliminary design

We use the jacket model to optimize the members of the Innwind jacket [1], when subjected only to a static load. The force is a sum of a large thrust force, and the rotor nacelle assembly mass: $\mathbf{P_T}$ = 2 970 *kN* & $\mathbf{P_M}$ = 6 760 *kN.*

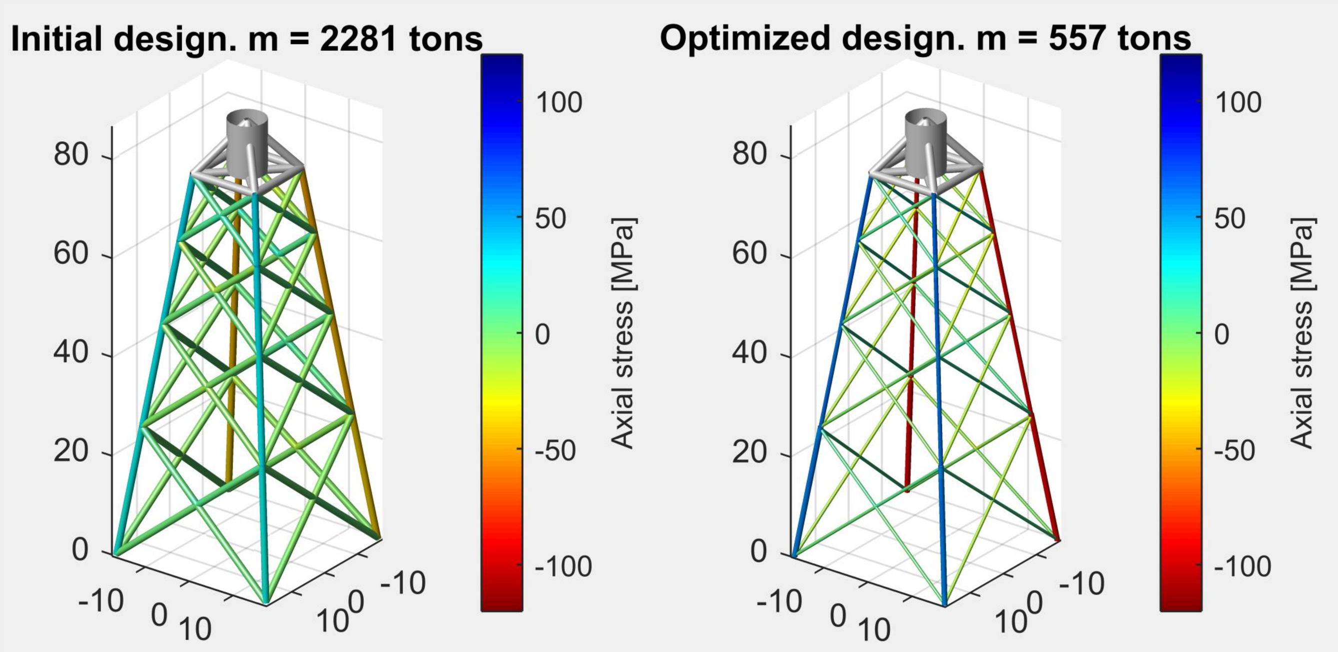

Figure 2: Initial and optimized design.

Table 1: Upper and lower bounds on the constraints.

	Lower bound	Upper bound
Diameter [*m*]	0.6	2.0
Thickness [*mm*]	20	100
Stress [*MPa*]	-90	90
Frequency [*Hz*]	0.16	0.30
Displacement [*m*]	-1.25	1.25

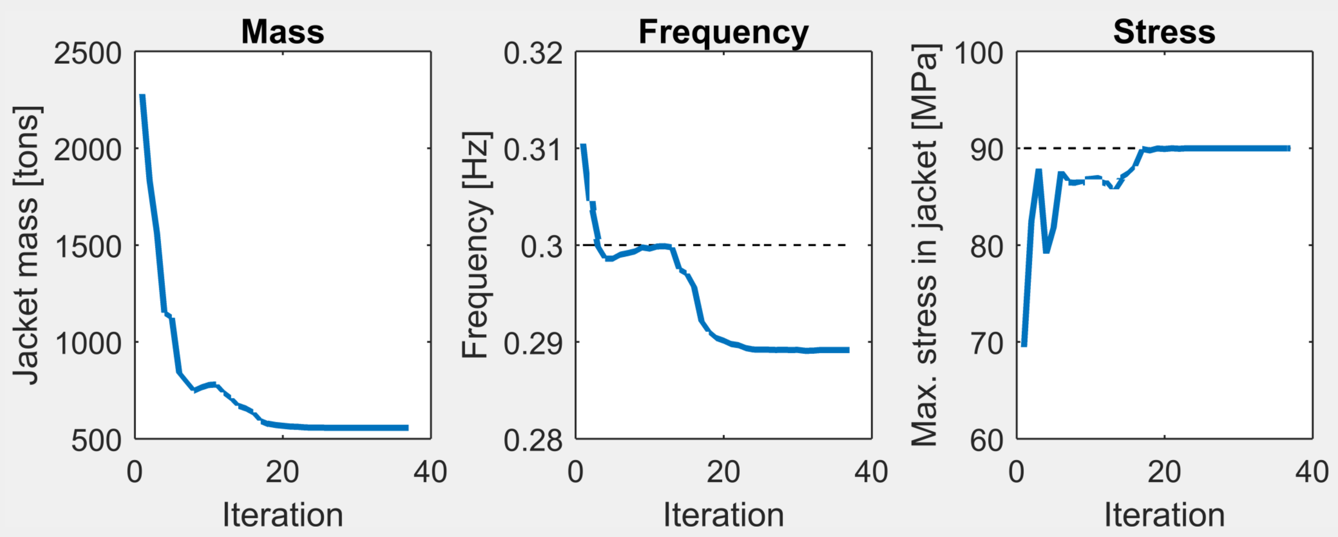

Figure 3: Optimization history. Time: 95 seconds (9.5 in IPOPT [2]) on 2.1 GHz, 8.0 GB RAM.

Table 2: Optimal diameter and thickness for the legs and braces.

	Sec 1	Sec 2	Sec 3	Sec 4
D Leg [*m*]	1.04	0.79	0.81	0.85
T Leg [*mm*]	34	50	51	53
D Brace [*m*]	0.6	0.6	0.6	0.6
T Brace [*mm*]	0.2	0.2	0.2	0.2

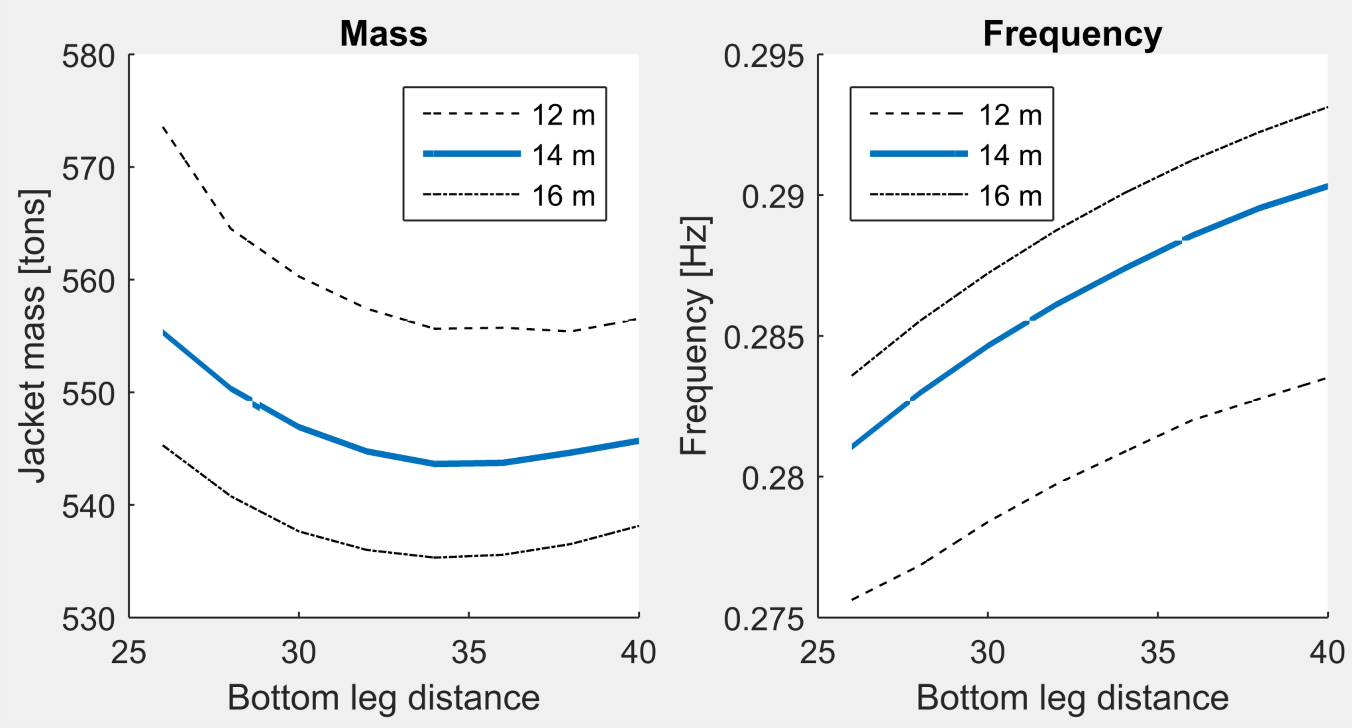

Figure 4: Parameter study on the influence of leg distance.

Parameter study

Let the bottom leg distance of the innwind jacket change from 26 *m* to 40 *m* (34 is the original). We then optimize the jacket for each bottom leg distance. In Figure 4, the different lines are different top leg distances.

Conclusion

Model, method, and a numerical example of preliminary design optimization of jackets is presented. The method works well, and current research aims to improve the model such that the numerical examples become more realistic.

[1] Borstel von B, Design report - Reference Jacket, Innwind, 2013.
[2] A. Wächter and L. T. Biegler, On the Implementation of a Primal-Dual Interior Point Filter Line Search Algorithm for Large-Scale Nonlinear Programming, Mathematical Programming 106(1), pp. 25-57, 2006.