Design optimization of jacket structures for mass production

This thesis presents models and applications for structural optimization of jacket structures for offshore wind turbines. The motivation is that automatic design procedures can be used to obtain more cost efficient designs, and thus reduce the levelized cost of energy from offshore wind.

A structural finite element model is developed specifically for the analysis and optimization of jacket structures. The model uses Timoshenko beam elements, and assumes thin walled tubular beams and a linear elastic structural response. The finite element model is implemented in a Matlab package called JADOP (Jacket Design Optimization), and the static and dynamic structural response is verified with the commercial finite element software Abaqus. A parametric mesh of the offshore wind turbine structure makes it relatively easy to represent various structures from the literature, as well as exploring conceptual designs. Stress concentrations in welds are modelled using design dependent stress concentration factors. Simplified models are also implemented for both piled foundations and suction caissons. Wind and wave loads are applied according to a realistic offshore environment.

An optimal design problem is formulated to optimize the design of the jacket structure using analytical gradients. The diameter and wall thickness of the jacket members are considered as design variables, making it a sizing optimization problem. Structural integrity constraints are implemented based on the relevant industrial design guidelines. These constraints include fatigue damage in the welded joints, shell buckling, and yield stress. The most challenging structural integrity constraint is fatigue, as it generally requires computationally expensive time-domain simulations. A simplified fatigue constraint based on damage equivalent loads is presented, and results indicate that the method gives realistic designs. The objective and constraint functions, including sensitivities, are implemented in JADOP, and this package is used throughout the thesis.

The devised framework is applied to the optimal design of jacket structures and foundations, with continuous and discrete design variables. Design criteria such as mass, fatigue, stress, and frequency are considered, and the validity of the modelling assumptions are investigated with aeroelastic simulations. The proposed framework can thus be applied to automate the design of jackets and foundations, and be a powerful tool in the whole design process of offshore wind turbine structures.

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