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Gradient based structural optimization with fatigue constraints of jacket structures for offshore wind turbines

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Abstract

In recent years a clear tendency in wind energy industry is to install larger wind turbines further away from coastal areas where wind conditions are more favorable. Generally, this will result in larger support structures of the wind turbines due to an increase in water depth, wind and wave loads. Performing structural optimization with fatigue constraints of the support structure may result in lower mass, effectively reducing the cost of the support structure. Thus, the main objective of this work is to develop and implement efficient gradient based structural optimization of jacket support structures with fatigue constraints for preliminary design, where the key challenge is to efficiently deal with numerous non-linear fatigue constraints and very large time-history loads.

A gradient based optimization framework has been established and demonstrated on the OC4 UpWind jacket structure, which is modeled using a 3D beam finite element program. The loads are based on aero-elastic time-marching multibody simulations of the wind turbine. The diameter and thickness of each steel member in the structure are optimized to reduce overall mass, while being subjected to constraints formulated by Palmgren-Miner's linear damage hypothesis. A comparative study on the effectiveness of the adjoint design sensitivity analysis determined from analytical expressions with aggregation functions and an active set strategy has been performed. Sensitivities are verified using a finite difference approach. The findings will give clear indications on effectiveness of different methods to perform fatigue design sensitivity analysis on structures subjected to large time-history loads, while also offering insight into different optimization formulations of the design problem. In short, this study presents a gradient based method for 3D structural optimization with fatigue constraints capable of application to many high-cycle fatigue driven structural design problems.