Popular Scientific Abstract

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Studies in the Fatigue Lives of Offshore Welded Joints Considering Non-Proportionality and Stochastic Effects

Metal fatigue is an important subject in the design of offshore wind turbine foundations. Generally, two main types of bottom-fixed foundations exist, namely monopile foundations and jacket foundations. Jacket structures are often preferred when the water depths get moderate to deep, compared to the monopile foundations. The jacket structure consists of circular hollow section beams which are welded together to form a truss structure. Especially, the welded connections (joints) between the trusses are prone to fatigue damage. In order to withstand the fatigue loading, the joints locally have to be thick which considerably increases the costs of jacket foundations.

To reduce the costs of jacket foundations, an optimization framework for offshore welded joints has been developed in this thesis. The framework is easily adaptable and can be used for many types of fatigue analyses. Furthermore, the optimization framework is capable of effectively taking into account the effect of non-proportional loads and the random effects occurring in the weld. For this to be possible, research into the effect of non-proportional loading and uncertainties in weld modelling have been conducted.

Welded joints in jacket foundations are exposed to multiaxial non-proportional loading which is known to decrease the expected lifetime (fatigue life) of the structures. The governing guidelines for design of offshore jacket foundations do not accurately take this into account as they do not identify and quantify the level of non-proportionality. Instead, they propose so-called penalty factors to take into account the additional damages from non-proportional loading. However, the penalty factors are not well described and no information about whether the penalty factors can be scaled for different types of loading and if the penalty factors can be reduced for certain load cases are given. In this thesis, the additional fatigue damage from non-proportional loading has been examined and a new approach for quantifying the level of non-proportionality has been developed based on the so-called principal component analysis. The approach is easy to implement in the fatigue calculations and as opposed to many of the approaches found in literature, it can be easily interpreted. The approach is then implemented in fatigue calculations and shown to be able to automatically determine the relevant penalty factors for accurate fatigue assessment.

Randomness and variability in material properties, geometry, loading and manufacturing need to be taken into account in the jacket design as well. In most developed methods, the randomness is considered as only a single random parameter, whereas the randomness, in reality, varies over the entire structure (stochastic). In the thesis, stochastic stiffness matrices for use with the finite element method have been developed that are easy to implement. Furthermore, the weld properties have been modelled using a new approach denoted the stochastic size effect that effectively takes into account that larger and longer welds are at higher risk of failure as opposed to smaller and shorter welds. This is accredited to more defects and errors in longer welds as opposed to shorter welds. Using this method, the quality of the welding can be simulated and used to predict more accurate fatigue lives.

By implementing the proposed method for non-proportionality quantification and the new stochastic size effect in the developed optimization framework, optimization of a cast steel joint in a jacket foundation has been performed. By optimizing the locations of the welds in the cast steel joint, large mass savings and thereby cost savings can be achieved.