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Influence of Joint Flexibility on Local Dynamics of a Jacket Support Structure

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The effect of different modeling techniques of the local joint flexibility on the local dynamics of a jacket support structure for an offshore wind turbine is investigated. Two numerical models of a jacket supporting a generic turbine are analyzed in the aero-hydro-servo-elastic tool ADCoS-Offshore. The first model is set up with Euler-Bernoulli beam elements, while the second model utilizes superelements for the joints' representation and Euler-Bernoulli beams for the remaining parts of the structure. Time-domain simulations are run for deterministic and stochastic load cases, and local jacket dynamics are investigated. The local response of the braces is compared with the global response at the jacket legs in terms of power spectral densities (PSDs). Damage equivalent loads (DELs) are calculated at several positions along the jacket to capture the impact of local and global dynamics on those loads. It is observed that the superelement model leads in general to higher fatigue loads than the beam model. A methodology to remove the global motion component from the displacement time history of the brace central joint is discussed. Larger displacements of the brace central joints are observed for the superelement model than for the beam model. It is recommended to use superelement modeling technique for a more accurate representation of joints in the jacket support structures.

INTRODUCTION

The analysis of Offshore Wind Turbines (OWTs) relies on aero-hydro-servo-elastic simulation tools. These time-domain-based tools account for an interaction of various environmental loadings and for the entire structural assembly of the OWT, including its control system. Due to a high simulation effort involving a large number of load cases, relatively simple beam models are commonly used for modeling the OWT support structures in those tools, as described by Vorpahl et al. (2014). Those modeling techniques incorporate simplifications that may lead to inaccuracies when simulating multi-member support structures.

In case of structures consisting of slender tubular members, Euler-Bernoulli beam elements should usually lead to a sufficiently accurate representation of the global structural loads. However, some differences in the global structural loads were observed by Vorpahl et al. (2014) and Tu and Vorpahl (2014) in the cases of OWTs with tripod and jacket support structures, respectively, when modeled with techniques other than Euler-Bernoulli beam theory. Also, over- or underestimation of local loads at the joints and the surrounding structural elements is possible in such cases.

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In reality, at the joints a tubular member is welded to another one at its outer wall, resulting in deformation of the outer sections of the chords – bending of a brace leads to a local indentation of the chord. Such an effect cannot be accurately reproduced with simple beam elements that are clamped at the intersection of the centerlines of a joint's tubular members. The members' central axes at the joints are almost unaffected by translational or rotational movement in the vicinity of the connecting points (nodes). This impacts the Local Joint Flexibility (LJF).

There are also other methods for considering LJF in space-frame structures modeled with beams. For example, an additional node at the outer wall of the chord may be introduced, where local stiffness can be modeled with axial and/or rotational springs or alternatively by short flexible beam elements. Nevertheless, none of these methods can be considered as accurate as the one where modeling of joints with shell elements is implemented. To obtain correct spring stiffness in different load directions is not a trivial task. These stiffnesses are usually derived with the parametric formulas (Buitrago et al., 1993) that are based on the analysis of shell models. More detailed description on the current state of practice for modeling joints in jacket support structures of OWTs can be found in Dubois et al. (2013).

To overcome these limitations, shell elements may be used for a more precise modeling of joints. Deflections at a joint modeled by using shell elements are usually larger than those obtained from a beam model, whereas bending moments are reduced as the joint connections are softer (Karamanos et al., 2010). Similar conclusions were derived by Chung and Cheng (1996) and Cheng and Chung (1997), who modeled elastic joints with translation and torsion springs. Moreover, modeling of LJF would affect the dynamic