Long-term fatigue analysis of multi-planar tubular joints for jacket-type offshore wind turbine in time domain

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Abstract

Long-term fatigue analysis of welded multi-planar tubular joints for a fixed jacket offshore wind turbine designed for a North Sea site in a water depth of 70 m is performed. The dynamic response of the jacket support structure due to wind and wave loads is calculated by using a decoupled procedure with good accuracy (Gao et al., 2010). Hot-spot stresses at failure-critical locations of each reference brace for 4 different tubular joints (DK, DKT, X-type) are derived by summation of the single stress components from axial, in-plane and out of plane action, the effects of planar and non-planar braces are also considered. Both a 2-parameter Weibull function and generalized gamma function are used to fit the long-term statistical distribution of hot-spot stress ranges by a combination of time domain simulation for representative environmental conditions in operational conditions of the wind turbine. A joint probabilistic model of mean wind speed $U_w$, significant wave height $H_s$ and spectral peak period $T_p$ in the northern North Sea is used to obtain the occurrence frequencies of representative environmental conditions (Johannessen, 2002). In order to identify the contributions to fatigue damage from wind loads, wave loads and the interaction effect of wind and wave loads, 3 different load cases are analyzed: wind loads only; wave loads only; a combination of wind and wave loads. The representative environmental condition corresponding to the maximum contribution to fatigue damage is identified. Characteristic fatigue damage of the selected joints for different models is predicted and compared. The effect of brace thickness on the characteristic fatigue damage of the selected joints is also analyzed by a sensitivity study. The conclusions obtained in this paper can be used as the reference for the design of future fixed jacket offshore wind turbines in North Sea.

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1. Introduction

The role of wind energy in renewable energy utilization is becoming more and more important. During the last 13 years (1996–2009), the global cumulative installed capacity of wind energy increased with an average annual rate of 28.6% [1]. Compared with land-based wind energy, there is more available space, more stable and higher wind speed, and less visual disturbance and noise for offshore wind energy. So offshore wind technology is growing fast, e.g. a significant growth of the offshore wind energy in the years 2010–2015 is expected to be more than 40% [2] in Europe.

The support structure has been identified as a vital contribution to cost-effective installations especially in deep waters [3]. Up to now, offshore fixed wind turbines with monopile and tripod foundations are mainly used for shallow water depths of 20–30 m, while research work is ongoing for larger water depths like 40–100 m where jacket structures are commonly used in the oil and gas sector. Now, jacket substructures are at an early stage of their development for use in offshore wind and have a good potential to develop to an esteemed solution through further development of the industry and methods employed for mass fabrication and installation [3]. During 2006, two prototypes of the Repower 5 M (5 MW) wind turbine with jacket foundations have been installed in water depths of up to 45 m. These two turbines form a ‘demonstrator’ project to investigate the feasibility for a later offshore wind farm of 200 turbines [4].

For OWTs (Offshore Wind Turbines), the wind load will influence the dynamic response of jackets more significantly than traditional jacket platforms used in the offshore petroleum industry, and the load level of the fatigue loads as well as the number of load cycles to be considered is considerably higher. The number of load cycles generated from the rotor of a wind turbine within the design life-time of 20 years usually reaches more than $1 \times 10^9$ load cycles [5]. Therefore, the fatigue performance of welded connections is a design-driving criterion for many structural details of OWT (Offshore Wind Turbine) support structures. In several previous studies Klose and coworkers [5] did an integrated analysis of