Fatigue life analysis of monopile foundation offshore wind turbine under coupled multiple loadings

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ABSTRACT

Offshore wind turbine (OWT) gradually attracts people’s attention for solving energy shortage and environmental pollution. The fatigue analysis of OWT is our research emphasis, since OWT fatigue damage is one of its main forms of damage during the long term. This paper focuses on the fatigue problem of the monopile foundation OWT under coupled loading. In order to solve the above problems, this paper uses a method to construct effective strain data. In addition, this paper uses finite element method (FEM) to conduct fatigue analysis for the monopile foundation OWT model by using S-N curve and Miner’s rule. The fatigue life of the OWT model is considered under the influence of wind and wave. In this paper, a complete analysis procedure from displacement to strain and from strain to fatigue damage of OWT is obtained, which is of great significance to fatigue analysis of OWT and makes it possible to obtain the fatigue damage of actual OWT in real time.

KEY WORDS: offshore wind turbines; fatigue life; S-N curve; FEM

INTRODUCTION

With the development of society, energy shortage and environmental pollution has aroused attention, the utilization of clean energy has become more and more important. China's abundant wind energy resources and the maturity of offshore wind power technology make the wind power industry gradually transfer from land to sea. Compared with the land, OWT has to endure more complex environment, such as wind, waves, currents and corrosion and so on, which put forward great requirements for the development of the OWT industry. During the lifetime of the OWT, the loading cycle times of reciprocating changes such as environmental loadings can reach more than 10^6. Excited by the cyclic loadings, the weak or stress concentration part of the OWT always occur fatigue failure. As a result, the research to avoid fatigue failure of OWT become a significance work for scientists. Li Wei (2011) considered the influence of different loading sequence on fatigue properties, conducted fatigue analysis on OWT foundation structure, and further explained that miner’s law did not consider the influence of loading sequence. Mo Jihua (2011) analyzed the fatigue of monopile foundation OWT and pointed out that wind load was the main factor affecting OWT fatigue. Ju Shenhaw (2019) proposed a fatigue analysis and design method, which is suitable for non-contact support structures by using the method of parallel calculation to determine the fatigue life. Li Haoran (2018) studied the short-term fatigue failure properties of SPAR floating OWT under random wind and wave loadings, and considered the effects of simulated length, wind and wave misalignment, wind effect and wave effect on fatigue damage. Lin Chen (2018) proposed a method to describe wave flow interaction model and use it to SPAR OWT fatigue analysis. Rui Teixeira (2019) studied the uncertainty of the definition of loading spectrum in fatigue calculation of OWT, and also analyzed the damage density under different environmental conditions. Zhao Jianbin (2019) compared the time-domain method with the frequency-domain fatigue analysis method, and came to the conclusion that the wind-induced fatigue damage obtained by the frequency-domain method using the Dirlik model was close to that obtained by the time-domain method, but the superimposed total fatigue damage was smaller than the total damage caused by the combined action of wind and waves. Qin Peijiang (2017) used frequency domain method to analyze fatigue of OWT support structure. However, the frequency-domain method is more effective for fatigue damage caused by one kind of loading. Considering only one kind of loading will cause larger error, and the frequency domain method is not applicable to the fatigue analysis under the combined action of wind and wave. The time domain method is more suitable for fatigue analysis of OWT. Sheng Zhenguo (2014) presented a set of time-domain fatigue analysis method and used it to conduct fatigue analysis of offshore wind turbines in wind and wave environment. Ma Yongliang (2012) used the loading superposition method to analyze the fatigue of the tower structure of OWT under the combined action of wind and waves and compared it with other methods such as full coupling method, stress superposition method, and damage superposition method were used to analyze the fatigue of OWT.

In this paper, aiming at the difficulty of obtaining the strain on the OWT, a theory of using easily accessible displacement to transform strain is proposed. In addition, the whole process of fatigue analysis is described, and the fatigue life of the monopile OWT is obtained under the action of wind, wave and their combination, which is of guiding significance to the life of the OWT.

NUMERICAL METHODS