Ships and Offshore Structures, 2015
http://dx.doi.org/10.1080/17445302.2015.1099245

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Performance-based assessment of steel jacket platforms by wave endurance time method

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(*Received 9 May 2015; accepted 21 September 2015*)

In this article, wave endurance time (WET) is addressed as an applicable method for performance-based assessment of fixed offshore structures under extreme waves. In this method, inspired by the endurance time method in the field of earthquake engineering, artificial wave records called wave functions are designed so that their excitations gradually increase with time. Therefore, the main advantage of the proposed method is that it can assess the structural performance under various wave load conditions through a single time-history analysis. Moreover, the reliability of structures can be evaluated on the basis of the time that the structural response is still acceptable. In this study, generation of these artificial records and their application to assessment finite element model of a fixed offshore structure are described based on the extreme waves of the Persian Gulf. In order to consider the accuracy of this method in estimation of the structural response, finite element method is utilised to compare the results of the WET method with the results of typical 3-hour random records. It is concluded that WET is a computationally attractive method to estimate the structural response with reasonable accuracy.

Keywords: performance-based assessment; steel jacket platforms; wave endurance time; wave function

1. Introduction

The assessment of offshore structures under extreme wave conditions is an important step in the design procedure. In this way, various analysis methodologies have been proposed and each of them has its own advantages and disadvantages. The ability of these methods can be evaluated from the viewpoints of accuracy, reliability, convenient, computational costs and overall capabilities of the analysis. Some of the available methods that can be used in the assessment and the performance-based design of offshore structures under extreme wave conditions are shown in Figure 1.

One of the common methodologies is the static wave analysis recommended by various standard codes and researchers (API RP2A-WSD 2007; ISO 19902 2007; Karadeniz et al. 2009; DNV-OS-C101 2011; Abdel Raheem 2014) for the evaluation of offshore structures and the especially jacket platforms. This method considers the structure under the design wave height and associated wave period and neglects the platform dynamic response and the irregularity in the wave profile. The response spectrum analysis method can consider the dynamic effects, but due to the nature of the wave loading, the response spectrum is dependent on the geometry of the offshore structure (Tung 1986). By comparison, the time-history analysis method is more potent in assessment. It can consider different sources of nonlinearity, such as material and geometric nonlinearities. The pushover analysis is another method used in the design and the performance-based assessment of offshore structures. In this method, the structure is subjected to the design wave load, and the associated load pattern increases monotonically until the overall collapse of the structure. To achieve more accurate results, it is also proposed that the load pattern is updated according to the return period (Ronalds et al. 2007).

Recently, the desire to optimal design together with enormous growth of computer technology has motivated the scientists and engineers to use the time-history-based methods for the assessment of offshore structures under various sea states. In recent years, several researchers have proposed novel approaches for such assessment, especially for fixed offshore structures. As an appropriate substitute to the pushover approach, the incremental wave analysis (IWA) has been introduced to estimate different limit states and accurate response of offshore structures under extreme waves (Golafshani, Bagheri et al. 2011). Moreover, the probabilistic incremental wave analysis (PIWA) is a probabilistic framework which can consider the uncertainties in the structural response, collapse capacity and wave force parameters (Golafshani, Ebrahimian et al. 2011). In the random time-history analyses of the IWA and the PIWA methods, it has been proposed that instead of conducting 3-hour dynamic analysis, only 60 s of the sea surface elevation is considered in which the time of the maximum wave

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- The WET curves are well within the range of the results of 3-hour simulations. In addition, the average of WET curves gives a conservative estimate of the response obtained directly by the 3-hour analyses at different excitation levels. This curve is usually located between the mean and the mean plus one standard deviation of the 3-hour simulations;
- The computational burden of the WET method is significantly less than the equivalent 3-hour simulations (about 95% reduction in the computational costs);
- The WET results have a lower standard deviation. It seems that in comparison with the typical 3-hour time-history simulations, smaller number of WFs is necessary in the assessment procedure. However, the number of generated WFs is also low, and more studies should be performed in this field.

The WET method is in its early stages and additional studies are recommended to be followed:

- Testing the accuracy of the WET method in estimation of the structural response especially when there are major sources of nonlinearity;
- Testing a similar framework on other types of offshore structures, such as jack-up, tension leg, semi-submersible and spar platforms;
- Generating more WFs to study the scattering of the WET results;
- Investigating the accuracy and efficiency of the WFs generated on the basis of the more severe storm conditions and other study areas;
- Modifying the WFs generation process to consider more characteristics of the extreme waves.

Disclosure statement

No potential conflict of interest was reported by the authors.

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