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Assessment of offshore structures under extreme wave conditions by Modified Endurance Wave Analysis

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ABSTRACT

Recently, various approaches have been introduced to estimate the response of offshore structures in different sea states by stepwisely intensifying records. In this article, a more practical approach entitled Modified Endurance Wave Analysis (MEWA) considering the random and probabilistic nature of wave loading and utilizing optimal time duration is introduced. Generation procedure of this approach is described based on two practical wave theories: random and constrained new-wave. In addition, assessment of a simplified model representing a typical fixed offshore platform under extreme wave conditions in the Persian Gulf is performed making use of MEWA. A comparative analysis has been also carried out to investigate the accuracy and computational costs of MEWA. The results indicate that MEWA can be a time-saving and also reliable method both in design and assessment of offshore platforms.

1. Introduction

The main goal of evaluation of structures under extreme waves is to ensure that they can resist storm loading in different sea state conditions. In other words, the response of the structure must be

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acceptable for demanding requirements such as production activity, safety and serviceability of the offshore structure [1]. Also, changing in platform usage, modifications to the platform conditions and a re-evaluation of the environmental loading emphasize the necessity of assessment [2]. However, because of complicated geometries, Fluid Structure Interaction (FSI) and soil-pile-structure interaction, the assessment is a challenging procedure in offshore engineering practice.

Because of the dynamic nature and randomness of sea waves, time domain is a trustworthy method for accurate evaluation of structural performance especially in deep water and flexible structures [3]. In this method, dynamic behavior of the platform can be considered under random wave loading exerted to the members as a function of time. However, despite advantages of the time history method, it is conceptually complicated and time consuming and therefore it has limited application in usual assessment practices.

During the last few decades, several studies have been carried out to assess offshore structures under extreme wave loading such as Kjeøy et al. [4], Morandi et al. [5] and Vanraaij and Gudmestad [6]. Advances in computer processing power make it possible to analyze the platform under different extreme wave conditions using time history-based methods. Golafshani et al. introduced Incremental Wave Analysis (IWA) to assess the structural performance under various wave excitations [7]. Conceptually, they took advantage of Incremental Dynamic Analysis (IDA) which is a well-known method in seismic assessment of structures [8]. To overcome the computational cost limitations, they proposed that instead of considering a 3-h interval, it is practical to take into account only the maximum wave height of the record. This way cannot properly indicate the realistic nature of wave loading; therefore, the authors emphasized the possibility of obtaining unreliable results in other case studies. Zeinoddini et al. presented Endurance Wave Analysis (EWA) in which constrained new-wave is used as a reliable theory for simulation different extreme events [9]. In this method, time of the record is decreased significantly and a fixed time interval is utilized for each sea state. In addition, linear increase was proposed for representing the growing trend of the significant wave height.

Notwithstanding valuable advantages of the EWA, this method excludes the extreme value statistics in estimation of the response of offshore platforms. Moreover, this method requires modifications especially in selection of time duration and increasing trend. Modified Endurance Wave Analysis (MEWA) is a probabilistic approach offering a reliable procedure to acquire the optimum duration of the records and a practical way for increasing trend of the excitation. For considering the stochastic nature of wave loading, 500 time history records are generated, and extreme response distribution of the demand parameters is studied. Widespread use of return period in assessment procedures has convinced the authors to use this concept as increasing trend of the significant wave height. This method can be efficiently employed both for design and assessment of offshore structures.

2. Concept of EWA and MEWA methods

EWA is a new time history-based approach for estimating the performance of platforms by stepwisely increasing wave profile named Intensifying Wave Train Function (IWTF). Basic concepts of EWA method can be described by a hypothetical experiment as shown in Fig. 1. In this experiment, three different platforms with unknown dynamic characteristics are exposed to an IWTF. At the beginning, the structures are subjected to a time history wave loading corresponding to a certain significant wave height (H_s), peak spectral period (T_p) and time duration (t_d). Since the amplitude of the excitation is quite low, all three platforms remain stable after this loading. In the next steps, the significant wave heights increase linearly whereas time duration is the same as the prior one. As time goes on, a point is reached when one of the platforms (platform C) exceeds its serviceability limit. As time passes more, the excitation becomes severe, such that platform C collapses, platform A is damaged severely but platform B still continues its serviceability. According to this experiment, the more endurance time, the better structural performance. In this method, any reasonable Engineering Demand Parameter (EDP) can be considered and the analysis will be continued until the desired level of excitation has been covered.

Generally, in this study, three challenges in EWA method are considered and MEWA is proposed based on these points: