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Time-frequency Domain Characteristics on the Dynamic Response of a Moored Floater Under a Freak Wave by Wavelet Analysis

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Regarding freak wave actions on structures, the majority of existing studies focus on the time-domain statistical characteristics of floaters. For the limited frequency-domain studies available, they were analyzed by adopting a conventional Fourier transform, which cannot provide the variation of energy in a time series. However, a freak wave is a spike in a random wave series, and hence the local characteristics in a time domain are of key importance. Compared with Fourier transfer, the wavelet analysis method is more effective in obtaining the energy spectral density as well as energy distribution of each frequency in time domain, especially the instantaneous physical changes under freak waves. By adopting wavelet analysis, this study manages to figure out the time-frequency domain characteristics on the dynamic responses of the moored floater under a freak wave through extensively experimental investigations. The results show that the wavelet analysis method is effective in obtaining the energy spectral density and the energy distribution of each frequency in time domain. There is a significant variation on the time-frequency domain characteristics of the dynamic response under a freak wave. The energy parameter δ_E of surge, heave, and pitch in freak waves can be up to 2.48, 1.88, and 1.65 times of those under random waves, respectively.

INTRODUCTION

Many maritime accidents demonstrate that a freak wave is a serious hazard to offshore vessels and structures. Nowadays, more and more occurrences of freak waves have been observed in the oceanographic observations globally. Therefore, it is worth investigating the security of marine structures under freak waves. On the interaction between freak waves and structures, Clauss et al. (2003) investigated the motions behavior and splitting forces of the semisubmersible GVA 4000 under a freak wave through experimental measurements and time-domain simulation. It was found that the maximum response is subjected to freak wave height. Schmittner (2005) investigated the motions and bending moments of floating production storage and offloading (FPSO) and heavy lift vessels as well as the motions and splitting forces of a semisubmersible under a freak wave. The results showed that the vertical bending moments, heave and pitch of the FPSO and heavy lift vessels, and the air gap and splitting forces of the semisubmersible under a freak wave are larger than the maximum values predicted by codes and frequency-domain analysis. Shen and Yang (2013) compared the motion responses of a semisubmersible under two kinds of predetermined extreme wave sequences and analyzed the impacts of a freak wave and a “Three Sisters” wave (three rogue waves in succession) on platform motions. The results showed that the peak value of wave height is the key parameter in determining the dynamic response of the platform, which should be a concern in front-end engineering design study. With the same peak value, the maximum response of the platform increased with the spectral peak period and significant wave height. The adjacent effect in the "Three Sisters" wave has impacts on the platform motions, in which both the surge and heave of the platform increased with the adjacent wave heights. Deng et al. (2015) investigated the effect of mooring stiffness on the motion behaviors and mooring tensions of a semisubmersible platform. The measurements showed that the freak wave can lead to critical horizontal motions on a flexible mooring system and extremely huge mooring tensions on a tight mooring system. With the identical significant wave height H_S and spectral peak period T_P of the Pierson-Moskowitz (P-M) spectrum, Pan et al. (2018) compared the motion response of a moored square cylinder under freak and random waves and quantified the effects of relative wave height, relative period, and freak wave parameters on the floater motion response based on time-domain measurements.

The majority of existing research focused on time-domain statistical characteristics of the structures. Few studies have investigated the dynamic response characteristics of floaters in frequency domain. Through Fourier analysis, we can obtain the energy distribution, peak frequency, total energy, and each order spectral moment in frequency domain. But the frequency spectrum cannot provide the variation of energy in a time series. For a stationary process, the local frequency characteristics in a time series are probably not so important. However, as a spike in a random wave series, the local time-frequency domain characteristics are of key importance for the dynamic response of the floater under a freak wave, especially the instantaneous physical change under a freak wave. In this study, we performed wavelet analysis to investigate the time-frequency structural characteristics and variation under freak and random waves. Based on the work of Pan et al. (2018), this study made comparisons on the time-frequency domain dynamic responses of a moored square cylinder under freak and random waves (with an identical wave spectrum).

EXPERIMENTS

Experimental Setup and Model Parameters

The model was placed at the target location for freak wave occurrence, approximately 21 m away from the wave maker. The

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KEY WORDS: Motion responses, moored floater, freak wave, time-frequency spectrum, wavelet analysis.