A NUMERICAL STUDY OF FREAK WAVE GENERATION IN RANDOM SEAS OVER A SUBMERGED BAR

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1. INTRODUCTION

Freak waves, also called rogue waves and giant waves, are much larger and steeper than the surrounding waves, can cause severe accidents, and can be formed in both coastal and offshore regions. The past researchers on freak waves in coastal regions are mainly focused on the statistical properties, and the generation mechanism of such large waves are not yet discussed intensively. The aim of the present study is to examine the generation process of freak waves in unidirectional propagating random waves over a submerged bar using a fully nonlinear numerical wave model, SWASH. It was found that freak waves are readily formed at the seaward part of the crest of the bar and gradually emerged from an intense wave group. The enhancement of the bound higher harmonics in the shoaling process is the main reason to form such large waves in shallow water. On the crest bar of the bathymetry, the extreme wave gradually vanished, mainly due to the releasing of bound higher-harmonics to free wave components.

2. NUMERICAL MODEL

In this study, the well-known water wave model SWASH (Zijlema et al., 2011) is adopted to simulate random waves over a submerged bar, which has a long top crest. The sketch layout of the numerical flume is shown in Figure 1. JONSWAP spectrum is considered to simulate random wave trains. The peak enhancement factor γ = 3.3.The wave peak period is T_p = 1.5 s, and the significant wave height H_s = 0.03 m. A sponge layer with width of 8.2 m is placed at the end of the wave flume. The spatial horizontal grid size is dx = 0.01m and 5 uniform vertical layers are adopted. The total simulation time is 200 s for one wave train.

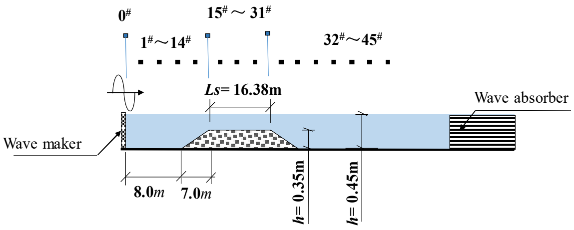

Figure 1 -Sketch layout of the numerical flume.

3. RESULTS DISCUSSION

From the simulation results shown in Figure 2, it is observed that in the offshore region, the wave profiles are symmetric about the mean water level and wave crests are relatively stable. Whereas, in the shoaling process, the wave profiles are asymmetric as their crests sharper than their troughs, and some large waves with steep crests are found at the top of the bar. On the crest of the bar, the crests of large waves continue growing and at x = 16 m reach the maximum, then with the wave propagation, the large waves fade away, and after at x = 20 m, the waves are gradually become stable again. By examining the generation process, at the instant of the occurrence of the freak wave, the amplitude of the

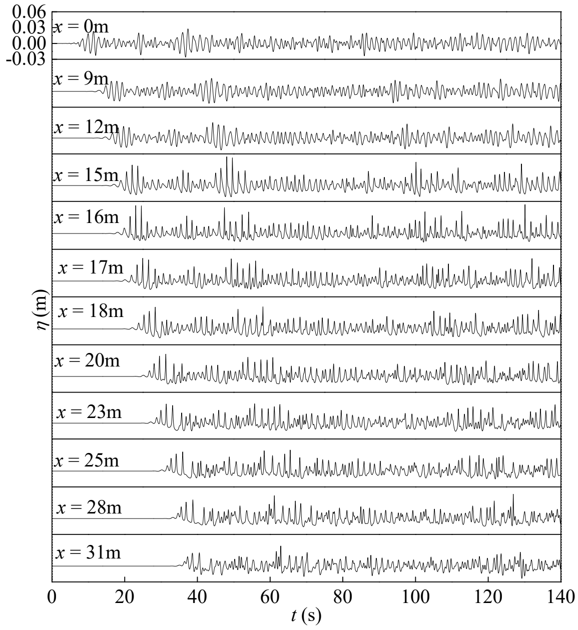

Figure 2 -The evolution of the surface elevations along the wave flume.

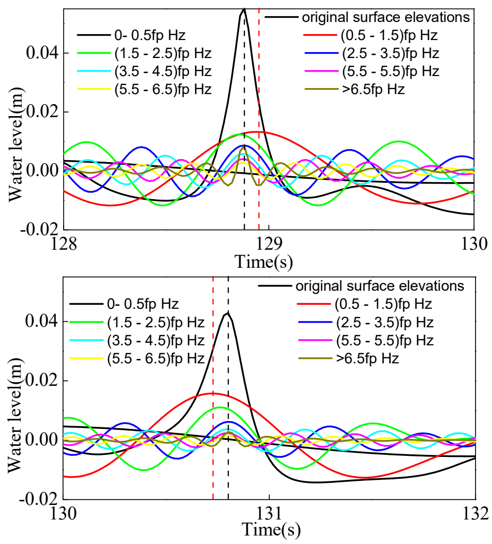

Figure 3 - Surface elevations for a freak wave and the corresponding harmonics; upper panel: at the instant of the freak wave; lower panel: at a downstream location of the freak wave.

second harmonic is almost equal to the primary wave and the higher-harmonics also contribute a lot. It is surprisingly found that the contribution of the harmonics with frequencies higher than 6.5fp is still not ignored (Figure 3). However, after the formation of a freak wave, the energy of frequency components larger than 6.5fp is decreased, and the maximum crest is gradually reduced due to dispersive propagating of different harmonics, which are realized as free waves at the crest of the bar.

In order to analyze the nonlinear phase coupling in the process of wave evolution, the wavelet-based bicoherence is used to reflect the triad interaction among wave components. Figure. 4 shows the contours of wavelet bicoherence *b* for the time series of the wave group at the selected locations. At the offshore location, *x* = 8m, the bicoherence spectrum indicates that only a few components participate in wave-wave interactions, and the degree of phase coupling is weak. For example, $b\,(f_p, f_p) = 0.2$, $b\,(2f_p, f_p) = 0.1$, indicates a weak self-self wave interaction at the energy-frequency peak coupled with the energy at twice the primary mode. With decreasing of the water depth, more and more wave components are involved in the nonlinear interactions, and the degree of phase coupling among harmonics are enhanced. At x = 16m, the degree of the triad coupling reaches to the maximum. Besides of phase coupling within the peak, between the peak and its higher harmonics and between the higher harmonics themselves, there are other modes participating in the nonlinear process. The bicoherence among the harmonics is mostly larger than 0.8, indicating that the higher-harmonics are obtaining energy from the primary waves and mainly bounded waves. Hereafter, the phase coupling between the high harmonics decrease, mainly due to the release of the bound higher harmonics.

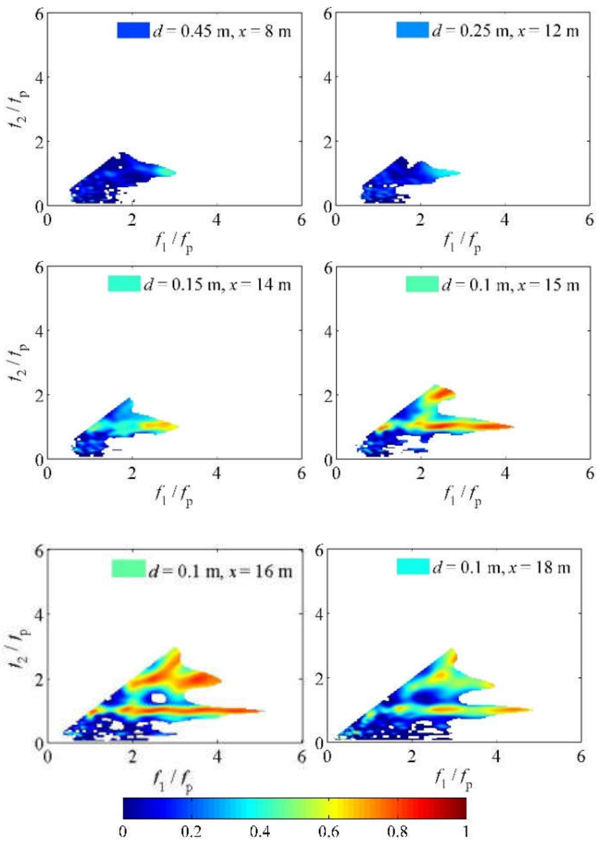

Figure 4 -Contours of the squared bicoherence spectra for the time series at the some selected locations.

By further simulating the propagating of an independent wave group which is obtained from the original wave trains, it is found that the freak wave formed in an independent wave group is the same as the giant wave generated in the corresponding long duration wave trains (see Figure 5), indicating that coastal freak waves are mainly generated in a specific wave group.

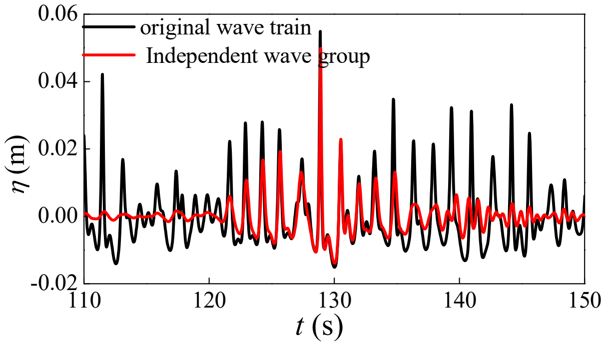

Figure 5 - Comparison of the surface elevations between the simulation of a whole wave train and an independent wave group at the instant of a freak wave.

4. CONCLUSION

The propagation of unidirectional random waves over a submerged bar with a slope 1:20 and a long crest bar is studied. The main objective is to assess the generation process and the mechanism of freak waves emerged in random waves. The well-known numerical wave model, SWASH, is used to implement the simulation. On the crest of the bathymetry, the large wave gradually vanished. In order to analyze the generation process of the freak wave, the surface elevations are decomposed into time series with different frequency bands. It is found that the generation of the freak wave is mainly caused by the enhancement of the higher harmonics in the shoaling process, the contribution of the higher harmonics of $f > 6.5f_p$ can not be ignored. At the crest of the bathymetry, the freak wave is gradually vanished mainly due to the releasing of the bound harmonics to the free components. The triad wave interactions are investigated using the wavelet-based bicoherence. Furthermore, the freak wave in the shoaling process is mainly formed locally in a wave group by examining the evolution of the isolated wave group in which the freak wave was formed.

5. ACKNOWLEDGEMENTS

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