PROPERTIES OF EXTREME WAVE GROUPS BASED ON MEASURED WAVE DATA

Ruili Fu, Hohai University, ruilifu@hhu.edu.cn
Gang Wang, Hohai University, gangwang@hhu.edu.cn
Jinhai zheng, Hohai University, jhzheng@hhu.edu.cn
Aifeng Tao, Hohai University, jhzheng@hhu.edu.cn

INTRODUCTION

Extremely large waves, also known as freak waves or rogue waves, are defined as $H > 2H_s$, where H_s is the significant wave height, H is the wave height (Dysthe et al., 2008). These waves have caused great damage to marine structures and human life in open seas and coastal regions. Many studies have demonstrated that an extreme wave evolve from a wave group in random wave trains. Shapes of extreme wave groups are strongly related to dynamic responses of structures. NewWave is a common theory to reflect the average shape of freak wave groups in the Gaussian process (Tromans et al., 1991). However, the differences of profiles based on the theory and measured time series have not been quantified in detail. In the paper, 1424 freak waves from various sea states in the Norwegian Sea are analyzed and their average wave shapes in each class of sea states are compared with those according to the theory, it is found that as the wave steepness is less than 0.08 and the spectral width parameter is smaller than 0.36, the NewWave theory can reflect mean extreme wave shapes rationally, whereas, for the sea states with the larger wave steepness or wider ocean spectrum, the energy of freak wave groups are obviously underestimated.

MEASURED DATA DESCRIPTION

In the paper, raw sea surface elevations measured by a ship-borne wave recorder (SBWR) from 2000 to 2009 at the Ocean Weather Station (OWS) Mike (at 66˚N, 2˚E) in the Norwegian Sea are investigated. After adopting quality control procedures for the datasets to eliminate spurious elevations caused by unavoidable measurement errors, the final dataset consists of 17296 30-minute records containing approximately 18 million individual waves. According to the definition of freak waves, the total 1424 freak waves in different sea states with the significant wave height varying from 3.0 to 10.0 m, the peak period varies from 6.0 to 16.0 s are obtained. Wave steepness and BFI of sea states occurring freak waves are shown in Figure 1, most freak waves are formed in the relatively wide ocean spectrum, which is inconsistent with the previous studies. Besides, modulational instability may not be an important factor to form rogue waves.

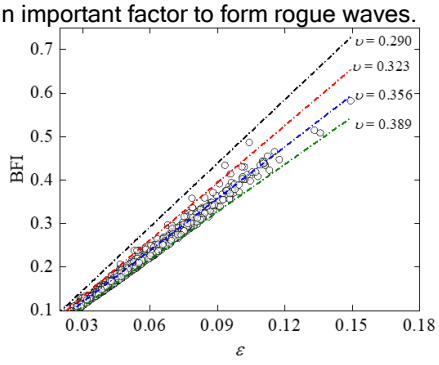

Figure 1 - Scattered distributions of wave steepness and BFI for the sea states where freak waves are generated.

RESULTS AND DISCUSSION

Profiles of extreme wave groups in different sea states are obtained and compared with those based on the NewWave theory (see Figure 2), it is found that the theory can predict mean measured shapes of extreme wave groups in weak nonlinear states with a narrow spectrum. However, differences between the theory and measured increase as the wave steepness larger or spectral width wider.

Furthermore, Variations of non-dimensional average energy of the two wave crests before and after the freak waves are shown in Figure 3, where the energy is divided by the square of the freak wave crests. In general, the energy based on the Newwave theory is smaller than the measured values, which has not been found in the previous studies.

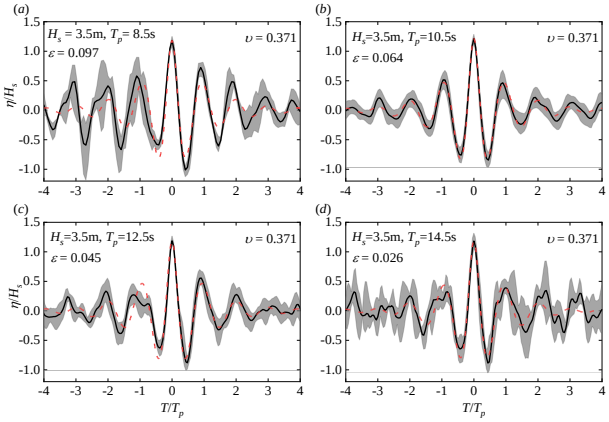

Figure 2 - Comparisons of the wave shapes between the extreme wave groups having the most probability and using the NewWave theory; ---: NewWave profile ηt; —: measured average wave shape; ▒ :95% confidence intervals.

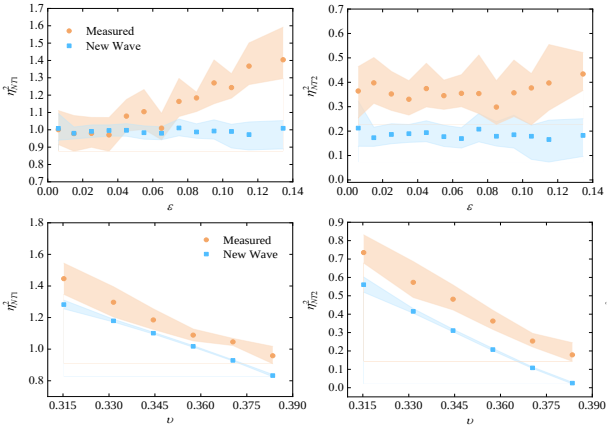

Figure 3 - Variations of non-dimensional average energy of the two wave crests before and after the freak waves.

To quantitatively compare the extreme wave groups based on the measured and the theory, the ratio of the non-

dimensional energy for the adjacent three wave crests of freak waves are defined as:

$$Ratio=\frac{\sum_{i=1}^{3}\eta_{iNTm}^2+\sum_{i=1}^{3}\eta_{iNCm}^2+\eta_{fm}^2}{\sum_{i=1}^{3}\eta_{iNTt}^2+\sum_{i=1}^{3}\eta_{iNCt}^2+\eta_{ft}^2}. \quad (1)$$

where the subscript m denotes measured, t denotes the theory, it is found that as the wave steepness is less than 0.08 and the spectral width parameter is smaller than 0.36, the NewWave theory can reflect mean extreme wave shapes rationally, whereas, for the sea states with the larger wave steepness or wider ocean spectrum, the energy of freak wave groups can be underestimated to one time.

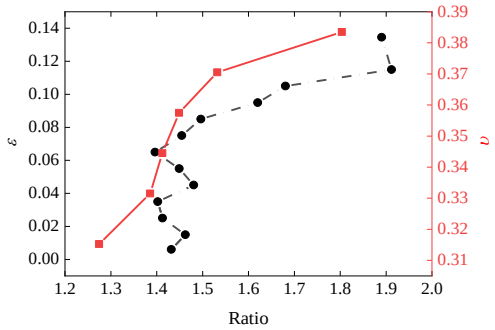

Figure 4 – ratio of the extreme wave group energy between the measured and NewWave theory in different sea states.

REFERENCES

Dysthe, K., Krogstad, H.E., Müller, P., 2008. Oceanic rogue waves. Annu. Rev. Fluid Mech. 40, 287-310.

Tromans, P.S., Anaturk, A.R., Hagemeijer, P., 1991. A new model for the kinematics of large ocean waves-application as a design wave, ISOPE International Ocean and Polar Engineering Conference. ISOPE, pp. ISOPE-I-91-154.