

Focusing Models for Generating Freak Waves

Zhaochen Sun¹, Xizeng Zhao¹, Yifei Zhang², Jiafa Shen²

¹ State Key Lab of Coastal and Offshore Engineering
Dalian University of Technology

Dalian, China

² Second Institute of Oceanography, State Ocean Administration
Hangzhou, China

ABSTRACT

Based on improved Longuet-Higgins wave model, four wave focusing models for freak wave generation (1. extreme wave model + random wave model; 2. extreme wave model + regular wave model; 3. phase interval modulation wave focusing model; 4. Number modulation wave focusing model with the same phase) are proposed. By using different energy distribution techniques in the four models, freak wave events are obtained with different H_{max}/H_s in finite space and time. Numerical simulations are carried out in a 2-D wave focusing model, which is presented based on enhanced high order spectral (HOS) numerical method and validated by comparison of numerical results with experimental and theoretical ones (linear waves).

The fully nonlinear model of formation of extreme wave is conducted based on the enhanced HOS numerical technique. By comparing the simulations with experimental study presented by Baldock (1996), validation of the numerical model is verified, and the importance of wave-wave nonlinear interactions is emphasized. Numerical results show that the divergence of surface elevation at the focus point from the linear input solution, the downstream shifting of focus time and the downstream shifting of the focus point result from the wave-wave nonlinear iterations. Improving Longuet-Higgins model, four focusing models of formation of small-scale freak waves are obtained. Investigations of parameter H_{max}/H_s characterizing freak waves appearing to depend upon the energy distribution methods are then realized. Adjusting energy distribution in the four models, freak wave phenomenon is achieved with different H_{max}/H_s in finite space and time. The present work is conducted without bathymetry, directional or current.

KEY WORDS: high-order spectral method; freak wave; wave focusing; Longuet-Higgins model; phase modulation

INTRODUCTION

In recent years the freak phenomenon in the ocean has become a topic of intensive study. Such a wave may lead to damage of ships and offshore platforms and to deaths (Tsai et al, 2004, Haver and Andersen, 2000). But due to the rare data in situ or remote observations of the actual wave fields and unexpected occurrence of freak waves, several

theories were suggested as possible explanations for this phenomenon. Their occurrence may be related to a wave energy focusing which derives from a number of factors: wave-wave interaction, wave-current interaction, bathymetry, wind effect, self-focusing instabilities, directional effects, etc. Kharif and Pelinovsky (2003) made a review on the different mechanisms of formation of freak waves. Freak wave events are defined traditionally as large waves whose heights exceed the significant wave height H_s (or $H_{1/3}$) by a factor in the range of (2.0-2.2). In the linear approximation, a random wave field can be considered as a Gaussian process. Under this assumption, a mathematical definition of a freak wave event can be expressed by $H_{max} \geq 2.0H_s$, H_{max} being the height of this extreme event. Accounting for nonlinearities in the process, a refined definition tends to raise the limit of the freak wave height to $H_{max} \geq 2.2H_s$. The latter limit of $2.2H_s$ is now commonly accepted. In this paper the definition of a freak wave is adopted as an individual wave whose height exceeds 2.2 times the significant height.

Due to the limit of physical flume length, none physical flume has ever been adequate to describe the full-scale freak wave which appears with long time evolution (Ducrozet et al, 2007, Wu et al, 2005). The progress in the research on formation of freak waves is mainly through laboratory studies using the methodology of laboratory-scale wave focusing (Baldock et al, 1996, Huang, 2002 b, Liu and Hong, 2004, Rui, 2004). The occurrence probability of freak wave of component waves with the initial phase distributing asymmetrically in a random sea have been described by Huang (2002 a) using theoretical analysis, who gave a low limit of defining freak wave. Kriebel (2000) summarizes an efficient procedure for generating freak waves by embedding an extreme transient wave within a random sea. Pei (2006) concerns the relationship between the parameter H_{max}/H_s and the energy percentage within the combined wave model (Kriebel, 2000). However, the wave-wave nonlinear interactions are neglected and the evolution of the space series is not concerned in their papers. In the present work an efficient and accurate numerical technique, called the higher order spectral method is introduced, which bases on potential superposition of component waves and FFT algorithm with application to fully nonlinear water waves.

The fully nonlinear model for generating extreme waves is conducted based on the enhanced HOS numerical technique. By comparing the