

Numerical Investigation of Multidirectional Wave Focusing Properties

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ABSTRACT

In the paper, the method for the generation of multidirectional focusing wave was described. A numerical model based on the High Order Spectral (HOS) method was developed, in which, the wave maker boundary condition was introduced to simulate the wave generation. The effect of the wave parameters such as the wave spectral type, center frequency, frequency width and the directional spreading on the focusing wave surface elevation, the generated maximum wave crest, the shifting of the focusing point and the wave spectrum are numerically investigated in the paper. The obtained results can be a good reference for the physical simulation of focusing extreme and breaking waves.

KEY WORD: Focusing wave; High order spectral method; Numerical model

INTRODUCTION

In general, wave focusing is one of the most important mechanisms that contributed to the large waves or wave breaking in ocean, which impose large or extreme forces on ship and offshore structures. Recently, the concept of a focused wave group has been used to represent the profile of the extreme wave. Many researchers had paid a considerable attention to the studies of wave focusing, with the aim of understanding physical mechanisms of creating large waves. Rapp and Melville (1990) studied breaking criterion associated with a focused wave group, and it showed that the deviation in the breaking location from that predicted by linear theory may be attributed to nonlinear effects, which become important as the amplitude is increased. Taylor and Haagsma (1994) showed that as a group focuses it becomes narrower and much higher than that linear theory would predict. Baldock et al. (1996) investigated nonlinear surface water waves undertaken in 2-dimensional wave flume by a large number of water waves were focused at one point in space and time to produce a large transient wave group. The results showed that the focused amplitude, shift of focusing point increased with the wave amplitude increasing.

However, the waves in ocean are multidirectional waves. The focusing wave was not only generated by the wave focusing of different frequency waves, but also generated by different directional

waves. The wave directionality has a definite effect on the wave propagation. She et al. (1994) examined the effects of directionality on the breaking waves and their kinematics by investigating two simple cases of a wave field: one formed by a single frequency with a uniform angular spreading, and one formed by multiple frequencies where each frequency had a specified angular spreading function. Their results showed that the height of the incipient breaking wave, crest elevation, crest-front steepness and vertical asymmetry factor strongly depend on the angular spreading. Wu and Nepf (2002) examined the effects of wave directionality on breaking-wave criteria. Their results showed that wave directionality and spectral shape can affect the local wave-shape parameters at the onset of wave breaking. Many numerical models can be used to simulate and investigate wave focusing. Brandini and Grilli(2001) carried out a 3D numerical study of spatial wave focusing using the Boundary Element model with an Eulerian-Lagrangian flow representation. Dommermuth and Yue(1987) and West et al.(1987) developed the High Order Spectral (HOS) method. It permits the fully-nonlinear simulation of gravity-wave evolution within periodic unbounded 3-D domains. But the original surface elevation and velocity potential should be given. Bonnely et al.(2004) extended HOS method to simulate the generation and propagation of focusing wave by introducing the concept of an additional potential that satisfied the non-homogeneous boundary condition. Compared to other methods, the spectral method has the properties of fast convergence and low computational costs. In this paper, a numerical model is developed based on the high order spectral method proposed by Dommermuth and Yue (1987). In the numerical model, the wave maker boundary is introduced to simulate the wave generation in wave flume.

In this paper, the general description on the generation of focusing wave is introduced. Based on the developed numerical model, the effects of the main parameters on the focusing wave properties are numerically investigated and some conclusions that can be good reference for the physical simulation of focusing waves are given.

GENERAL DESCRIPTION ON GENERATION OF FOCUSING WAVE

According to linear wave theory, the free water surface $\eta(x, y, t)$ for three-dimensional seas can be represented by the double summation model as

$$\eta(x, y, t) = \sum_{i=1}^{N_f} \sum_{j=1}^{N_\theta} a_{ij} \cos(k_i x \cos \theta_j + k_i y \sin \theta_j - 2\pi f_i t - \phi_{ij}) \quad (1)$$

where a_{ij} is the amplitude of component wave with the i th frequency f_i and j th direction θ_j , k_i the wave number and ϕ_{ij} the phase of wave component. N_f and N_θ are the number of the frequency and direction,