Numerical Simulation of Second-Order Multidirectional Irregular Wave Groups

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ABSTRACT
Based on the second-order wave theory, a new deterministic method for simulating irregular wave groups is proposed. The analyzed results demonstrate that the numerically simulated second-order waves satisfy the expected wave groupiness besides the prescribed wave spectrum. Further, the effectiveness and applicability of the proposed simulation method is verified by the numerical model used to simulate wave propagation. It is implied that the simulation method correct to the second-order would be suitable for the waves with medium to high steepness, while the linear simulation method is not appropriate. And the boundary value of the wave steepness is suggested.

KEY WORDS: Irregular wave; wave groups; nonlinear; numerical simulation

INTRODUCTION
Ocean waves propagating towards the shore-line usually have the tendency to appear in a succession of high waves, known as wave groups. The stability of the ocean structures becomes questionable if they are exposed to the action of a groups of waves with heights higher than the design wave. Hence, effects of the groupiness should be considered in the laboratory tests of the moored floating structures and the stability of the armour layer of breakwaters etc, and it is necessary to study on the simulation method of irregular wave groups for physical and numerical model tests.

Despite the success of earlier studies on the simulation of the sea wave groups, such as Funke and Mansard (1980), Xu et al. (1993), Yu and Gui (1998) and Liu et al. (2012) etc, these works are limited by the linear wave theory to the wave fields with small wave steepness. However, nonlinearity as an important characteristic of the ocean waves plays an important role in the water wave dynamics research. Our concern here are successive waves occurring naturally in open sea in the absence of nonlinearity. On the one hand, it is known that the superposition of linear wave components with given frequencies, amplitudes, and directions of propagation but independent phases produces the linear Gaussian approximation. In this case, the wave envelope spectrum can be completely determined by the wave spectrum, which induces that the simulation of irregular wave groups is equal to the simulation of the common random wave (Xu et al., 1993). Therefore, in theory, it is more appropriate for us to research the wave groups using the wave model including nonlinearity. On the other hand, many engineering problems associated with wave groups such as the coastal sediment movement and the low frequency motions of moored ships mostly occur in shallow water, where the nonlinearity characteristic of the sea waves is very obvious. So, for the engineering application, it is also necessary to consider the influence of wave nonlinearity on the irregular wave groups.

However, little research related to the simulation method of wave groups correct to the second-order can be found in the literature due to the complexity of the nonlinearity problem. The objective of our work is therefore to develop a new deterministic method to simulate irregular wave groups, which would consider the wave nonlinearity up to the second-order. The simulated second-order wave should satisfy the expected wave groupiness besides the prescribed wave spectrum. In this study, almost all the important features of ocean waves such as the nonlinearity, randomness, directionality and groupiness, have been retained.

NUMERICAL SIMULATION METHOD OF SECOND-ORDER IRREGULAR WAVE GROUPS

It is assumed that the random wave field can be simply decomposed into a superposition of linear free waves that satisfy the dispersion relation. The superposed wave is still linear. However, when wave steepness is big, we should solve the second-order wave velocity potential and the second-order wave elevation for the irregular waves, in which the interactions between component waves are considered.

The most common approach for the second-order interactions calculation is to consider the superposition of two regular monochromatic wave trains. In the present study, we have chosen to