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Second-Order Long Waves Around a Huge Man-Made Island

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ABSTRACT

The objectives of the present paper are to formulate a nonlinear diffraction problem of the long waves by a huge man-made island using the multiple scales perturbation method, and to investigate the effect of the second-order long waves around a huge man-made island. The formulas for the free surface elevation of the second-order long waves around a huge circular island are derived analytically from the solutions of linear and slow potentials. The numerical results for the case where the envelope of the incident wave train is a sine function are compared with the experimental results, and the influences of second-order long waves around a huge circular island are made clear.

INTRODUCTION

Moored structures, some small harbors in man-made islands and tension leg platforms have natural periods of the order of a few minutes; therefore, they are not resonated directly by wind waves whose typical periods are about 10s (Bowers, 1977; Mei, 1984; Sand, 1982).

However, real incident sea is not uniform, and the modulational periods of short waves can be in the range of a few minutes. In practical planning and engineering design for the above structures and the harbors, it is more important to investigate the effects of long waves induced by modulated short wave groups.

Therefore, it is the objective of present research to formulate the nonlinear diffraction problem for the long waves by a huge man-made island using the multiple scales perturbation method, and to investigate the effects of the second-order long waves around a huge man-made island. The same technique has been developed by Agnon and Mei (1985) for the two-dimensional problem, and Zhou and Liu (1987) have found the second-order low-frequency wave forces on a circular cylinder by using the same perturbation method. Mei and Agnon (1989) have examined the nonlinear resonance of long waves in a rectangular bay by groups of short waves.

This paper examines the formulation for a three-dimensional problem by Zhou and Liu, and extends their formulation to the computation for the free surface elevation of the second-order long waves around the huge circular cylinder, which is imagined as a man-made island. The governing equation of slow potential can be obtained by using the solvability condition of the boundary-value problem for third-order zeroth harmonic potential. The formulas for the free surface elevation of the long waves around the cylinder are derived analytically from the solutions of linear and slow potentials. The numerical results for the case where the envelope of the incident wave train is a sine function are compared with the experimental results, and the influences of second-order long waves around a huge circular cylinder are made clear.

MATHEMATICAL FORMULATION

Assumptions and Coordinate System

We consider a vertical cylinder with huge radius, a , being fixed on a horizontal sea bottom of depth, h .

The Cartesian coordinate system (x,y,z) is fixed on the undisturbed free surface; the z-axis coincides with the vertical axis of the cylinder and points upwards. For convenience, we have also employed a cylindrical coordinate system (r, θ, z) . This is shown in Fig.1.

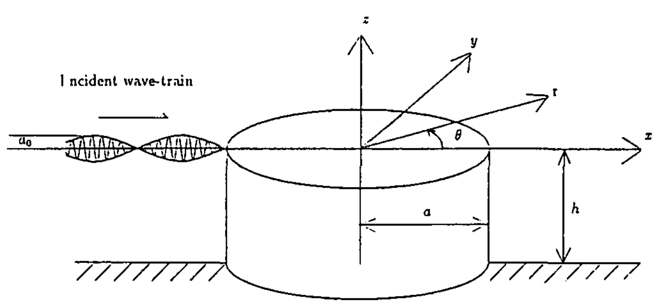

Fig. 1 Coordinate system

We assume that the fluid is inviscid and potential flow, and the incident wave train is nearly periodic with frequency ω. The envelope of the incident wave train modulates slowly in both x-direction and time t. For small-amplitude waves, $kA = O(\varepsilon) << 1$, where k is the wave number of the carrier waves, and the length and time scales of envelope modulation are $O(\varepsilon^{-1})$ times $2\pi/k$ and $2\pi/\omega$, respectively. Further, the cylinder's radius, a, is assumed to be comparable to the length of the wave groups:

$$ka=O\left(\varepsilon^{-1}\right)>>1. \tag{1.1}$$

Now, we express the slow scale of radius as:

$$a_1=\varepsilon a, \tag{1.2}$$

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KEY WORDS: Second-order long wave, huge circular island, nonlinear diffraction problem, multiple perturbation method.