International Journal of Offshore and Polar Engineering
Vol. 11, No. 4, December 2001 (ISSN 1053-5381)

Near-Resonance of Diffraction Waves by Array of Plates on Shallow Water in Oblique Waves

Takashi Tsubogo
Department of Marine System Engineering, Osaka Prefecture University
Sakai, Osaka, Japan

ABSTRACT

The near-resonance of diffraction waves by an array of plates rigidly fixed on shallow water is investigated under the assumption of linear long-wave theory. The plates are assumed to be identical, equally spaced along the array, and infinitely long in breadth. Near-resonant modes occur between adjacent plates at critical wave numbers in oblique waves. Considering the relationship between this near-resonant phenomenon and an eigenvalue problem of the wave diffraction, it is shown that near-resonant phenomena occur when a transmitted wave takes its maximum and the reflected wave vanishes. Relationships for the near-resonance between the wave incident angle and the wave number are confined in particular zones, called the resonant zones. Each *resonant zone* has $n-1$ curves representing near-resonance, where n is the number of plates. The width of the resonant zone itself is independent of the number of plates, but depends on the spacing of plates, wave number and incident angle. The resonant zone becomes narrow as the wave number or incident angle increases and the spacing of plates decreases. The relationship curve for the largest incident angle suggests the existence of a critical angle of the near-resonance. The amplitudes of near-resonant modes on the curves situated on both edge sides of each resonant zone become very large without limit as the number of plates increases.

INTRODUCTION

Certain resonant phenomena in a long array of cylinders in waves have been reported. Ohkusu (1972, 1975) investigated the interaction effects of diffraction waves by equally spaced rigid bodies on water-surface elevations and forces acting on each body. He reported the occurrence of standing waves. Takezawa et al. (1972) have studied hydrodynamic forces on a catamaran and obtained numerical and experimental results similar to Ohkusu's. Yoshida et al. (1993, 1994) have numerically and experimentally confirmed the occurrence of standing waves for a very large floating structure model supported by multiple columns. Maniar and Newman (1997) found at particular wave numbers very large free-surface elevations between adjacent cylinders in a large number of equally spaced vertical cylinders in waves, and correspondingly large in-line loads on each cylinder. Having related this phenomenon to *trapped waves* in a channel studied by Linton and Evans (1990), they have shown that the peak magnitudes of loads on each cylinder increase in proportion to the number of cylinders, but that the wave number bandwidth of peak loads becomes narrow. After Maniar and Newman's work, Kagemoto et al. (1998) investigated water-surface elevations along an array of cylinders in a head sea. They showed some modes of the water-surface elevation along the array. They numerically found that the near-resonant wave number of a 1-crest mode along an array of n (the number of cylinders) cylinders with the spacing Δx is identical to that of a N_v-crest mode along another array of $N_v \cdot n$ (the number of cylinders) cylinders with the same spacing Δx.

These near-resonant phenomena will occur in shallow-water waves. Under the assumption of linear long-wave theory, the author (Tsubogo, 1999, 2000) has investigated water wave diffraction by an array of plates fixed on shallow water in a head sea. Numerical facts may be summarized as follows. As the wave number increases, a 1-crest mode of water-surface elevations occurs at first along an array of 10 plates; subsequently 2-, 3-, 4- and 5-crest modes occur in turn, then inversely 4-, 3-, 2- and 1-crest modes occur. After this near-resonant wave-number zone, wave amplitudes decay from the head to the end of the array. Moreover, as the wave number increases, a series of the 1-, 2- , 3-, 4-, 5-, the 4-, 3-, 2- and 1-crest modes again occur in turn. There exist, one after the other and infinitely, near-resonant and decay wave-number zones. Further, a close relation exists between these near-resonant wave numbers and the transmitted and reflected waves.

This paper extends this analysis of wave diffraction by an array of plates fixed on shallow water. The principal objectives of this work are to show and explain the characteristics of the near-resonant phenomena. The effect of the wave incident angle on near-resonance is investigated. The relationships between the near-resonance, eigenvalues of the wave diffraction, and transmitted and reflected waves are considered.

DIFFRACTION PROBLEM FOR ARRAY OF PLATES FIXED ON SHALLOW WATER IN OBLIQUE WAVES

A 3-dimensional Cartesian coordinate system (x, y, z) is defined as shown in Fig. 1, where the x, y axes are horizontal, the z axis is vertical, $-h \le z \le 0$ is the fluid domain, $z = 0$ is the plane of the undisturbed free surface, and the depth h is a uniform constant. We consider an array of n equally spaced fixed plates on the water surface, each having length L with the spacing of plates, Δx. Each breadth of the plates is infinitely large in both directions of the $\pm y$ axes. Incident plane waves propagate in the direction with angle θ relative to the $+x$ axis with wave number k. The

Received October 6, 2000; revised manuscript received by the editors April 28, 2001. The original version (prior to the final revised manuscript) was presented at the Tenth International Offshore and Polar Engineering Conference (ISOPE-2000), Seattle, USA, May 28–June 2, 2000.
KEY WORDS: Wave diffraction, resonance, shallow water, hydrodynamic interactions, transmitted and reflected waves.