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Run-up and Wave Forces on an Array of Vertical Circular Cylinders: Experimental Study on Second-Order Near Trapping

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This paper summarizes the results of experimental tests conducted at the Danish Hydraulic Institute (DHI) in the framework of the EU-IHP-ARI project "Wave Forces on an Array of Circular Cylinders: Experimental Investigation on the Higher-Order Near Trapping." The aim of this research project was to study in detail the so-called near trapping, and specifically the 2nd-order near trapping. This phenomenon regards diffraction effects on TLP-like structures in waves or, in general, on arrays of vertical cylinders that encircle a portion of free surface (inner domain). The result of the wave-structure interaction is a rather large amplification of the oscillations of the free surface in the inner domain. These magnifications are particularly large at the fluid-body interface with associated, large induced pressures; they show their maximum effect for specific ratios of the column radius a to the incident wavelength λ (diffraction parameter ka) and of the column radius to the distance between the column axis d (a/d parameter). First-order near trapping occurs at the incident wave frequency, while 2nd-order near trapping is a double-frequency phenomenon that is expected to occur when double-frequency component waves exhibit a wavelength comparable to that of linear waves giving 1st-order near trapping. The paper describes the set-up of the experiments and the tests conducted, and finally presents the most meaningful results obtained. The behavior Vs ka of in-line and crosswise forces on the cylinders, of the wave run-up and of the free-surface oscillations at selected locations in the inner domain shows clearly the occurrence of the 2nd-order near trapping phenomenon with notable magnification factors.

INTRODUCTION

The problem of linear and nonlinear interaction between waves and an array of circular cylinders has been studied by many authors in the last 15 years. The basic motivation of these works has been a concern over loss of air-gap and the estimation of high-frequency loads in the diffraction regime on multicolumn structures.

Most theoretical studies have primarily focused on interference effects between the columns, and the results have been generally obtained in the framework of inviscid flow and linearised free-surface boundary conditions. In particular, Linton and Evans (1990) have shown that large magnification factors of global loads compared to the isolated cylinder case (MacCamy and Fuchs, 1954) can occur for specific values of ka and a/d. Their study concerns the case of cylinders whose axes are at the corners of a regular polygon. Linton and Evans relate the magnification of loading to the occurrence of near trapping of waves in the region inside the polygon, leading to enhanced free-surface oscillations. In the case of 4 cylinders at the corners of a square with waves travelling along the diagonal, it was shown that near trapping occurs for a wavelength λ approximately equal to $\lambda = \sqrt{2}d - 2a$. Fig. 1 shows a contour plot of the wave amplitude for $a/d = 0.275$ and $ka = 2.0$ in the linear near trapping condition, computed with the Linton and Evans method.

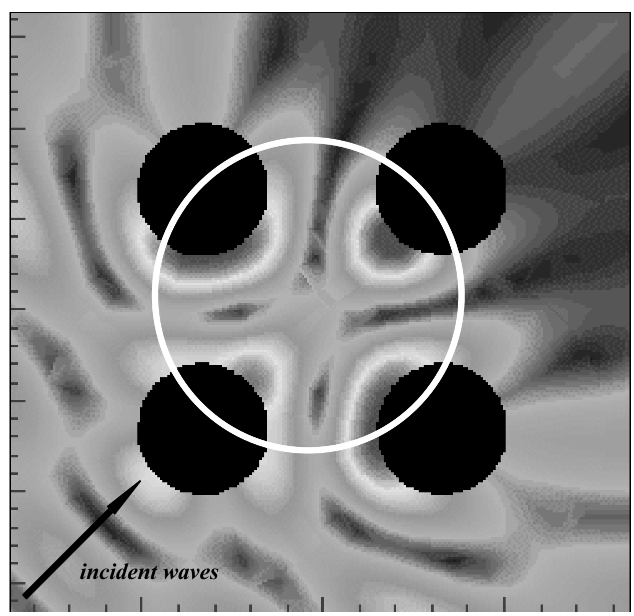

Fig. 1a Contour plot of wave amplitude for $a/d = 0.275$ and $ka = 2.0$ in linear near trapping condition (analytic solution obtained by Linton and Evans method, 1990)

Linear near trapping generally occurs for short nondimensional wavelengths ($ka \approx 2$); nevertheless, forces and run-up can exhibit large amplifications of order 10, compared to the isolated cylinder case (Linton and Evans, 1990). These short waves affect the fatigue life of the structure, but longer waves at lower ka can be even more important for the structural design. For instance, in the case of a slender vertical cylinder in long waves, Faltinsen et al. (1995) have shown that, for $A/a = O(1)$ and kA, $ka \ll 1$ (where A is the incident wave amplitude), the sum of the 2nd- and 3rd-order point forces acting at the free surface exhibits a relatively large oscillation as the incident wave crest passes with

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