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Analysis of Water Wave Problems Containing Single and Multiple Cylinders by Using Degenerate Kernel Method

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In this paper, water wave problems containing circular cylinders are solved by employing the null-field boundary integral equation in conjunction with degenerate kernels and the Fourier series. The fundamental solution is expanded to the degenerate kernel in the polar coordinates for problems containing circular boundaries. The boundary densities are expanded by using the natural base of the Fourier series. By this means, the field point can be located exactly on the real boundary free of calculating Cauchy and Hadamard principal values. Since errors attribute from the number of terms of the boundary densities, the present method can be seen as a semi-analytical approach. Both single and multiple cylinders are considered. Regarding the case of a single cylinder, our results are compared with those of the boundary element method (BEM) in the literature. The present method achieves higher accuracy and faster convergence than BEM. The near-trapped mode phenomena are observed. The effect of disorder of circular cylinders is also investigated in this paper. Finally, the free-surface elevation of the water wave containing a circular cylinder is animated by using the Mathematica software.

INTRODUCTION

Understanding the multiple scattering of water waves by arrays of cylinders is a problem of long-standing interest. Water wave problems containing circular cylinders have also attracted the attention of researchers from many countries with long coast lines, such as Taiwan, the USA and Japan. Over the past 40 years, investigators have presented several numerical methods, including the finite difference method, finite element method and boundary element method (BEM), to solve several problems in ocean engineering. In this field, water wave forces are of considerable importance for structures for structural safety, so many researchers have undertaken some related studies in different ways of theoretical, experimental and numerical work. MacCamy and Fuchs (1954) derived the exact solution of the horizontal wave force on a single vertical circular cylinder. The experiment data were tested by Chakrabarti and Tam (1975). Au and Brebbia (1983) employed the BEM to solve the water wave problems containing a circular cylinder. Later, Zhu and Moule (1996) used a various discretization mesh to obtain better results than those of Au and Brebbia (1983). Linton and Evans (1990) studied the interaction of water waves with arrays of vertical circular cylinders by using the multipole expansion approach.

Trapped and near-trapped modes may occur for problems containing infinite and truncated periodical patterns of arrays of cylinders, respectively, as shown in Fig. 1. Fig. 1a shows a trapped mode is associated with the existence of a real eigenvalue of the governing operator. Fig. 1b shows a near-trapped mode is associated with a singularity of the analytic extension of the governing operator close to the real axis. These physical phenomena appear in many fields, such as engineering mathematics, hydraulic engineering, earthquake engineering, ocean engineering and physics. The trap phenomena are described item by item.

• Engineering mathematics. When a spring system is subjected to an incident wave, the spring may have a near-trapped mode under a certain arrangement of spring constant and distance between 2 springs (Chen et al., 2009a).

• Hydraulic engineering. There exists a stepped ridge and that water is unable to propagate from a shallow area to a deep area (Mei, 1983).

• Earthquake engineering. Here, the surface wave may seriously result in damage for structures. For a thin-layer inclusion in a half-space medium, a trapped wave may occur—for example, the Love wave or the Stonely wave (Graff, 1975).

(a) (b)

Fig. 1 (a) Trapped mode of an infinite periodical array of cylinders; (b) near-trapped mode of a truncated periodical array of cylinders

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