Proceedings of the Tenth (2012) ISOPE Pacific/Asia Offshore Mechanics Symposium **www.isope.org**
Vladivostok, Russia, October 3-5, 2012

ISBN 978–1 880653 93-7: ISSN 1946-004X

Simulation of the Nonlinear Wave Elevation Around a TLP Platform

Bin Teng and Peiwen Cong
State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology
Dalian, P.R.China

ABSTRACT

A second order frequency-domain model implemented by a boundary element method was developed for wave elevation around structures. The diffraction of monochromatic waves by a square array of truncated cylinders and a simplified TLP was studied with this model, and the wave run up and the free surface elevation around the structures were presented. The computation results show that the near-trapping phenomena occurs inside the structures, which leads to increased wave height. Special concerns were paid on the examination of the carucial frequencies and maximum wave height of the near-trapping phenonmenon.

KEY WORDS: TLP platform, linear diffraction, the second order diffraction, free surface elevation, near-trapping

INTRODUCTION

An arrangement of four truncated cylinders centered at the corners of a square is a simple model of a typical TLP platform. The prediction of the run up on the cylinders is of great interest for the offshore industry, e.g. to determine the height of the platform deck above sea level. Evans and Porter (1997) indicated that wave interaction with four-cylinder structures can result in a considerable enhancement of the local free surface for particular incident frequencies over a very narrow range and the phenomenon is regarded as the near-trapping phenomenon. If these large free surface elevations were to occur in practice, then this would have serious implications for the design of large arrays of offshore structures. It is therefore important to understand when these effects occur and how they might be affected by factors, such as structure form and nonlinearity.

Although some interesting interaction effects that arise from nonlinearity have been observed, nonlinear effects are difficult to analyze with complex geometries. The nonlinear wave diffraction by a square array of truncated cylinders with horizontal pontoons has received relatively less attention. In present study, the wave interaction with a square array of truncated cylinders and a TLP platform is investigated in frequency domain based on a Stokes expansion approach. The velocity potential is obtained by a boundary-integral equation method. Numerical calculation is performed for the wave run up and the free surface elevation. Numerical results show the near-trapping phenomenon occurs inside the structures, which leads to increased wave height. With the ultimate aim of proposing tools for guiding airgap design, the phenomenon of near-trapping is investigated and consideration is given to the largest free surface elevation in the vicinity of the structures at crucial frequencies.

MATHEMATICAL FORMULATION AND METHODS

We consider the case when a fixed body is placed in an incoming wave system with angular frequencies ω, amplitude A and in a water of a depth of d. The coordinate system has the z-axis pointing vertically upwards and the origin is at the undisturbed free surface. The incident wave makes an angle β with the positive x-axis. We adopt the usual framework of potential flow theory, assuming that the fluid is incompressible and irrotational, so that the governing equation in the fluid becomes Laplace's equation for the velocity potential. The total velocity potential can be expanded in a perturbation series in terms of the wave slope parameter ε.

Here we are only interested in the periodic components. At each order, we depose ϕ into incident (ϕ_I) and diffracted (ϕ_D) potentials: $\phi^{(i)}=\phi_I^{(i)}+\phi_D^{(i)}$, i=1,2. The incident potentials are given from Stokes's waves. After introducing the perturbation series into the original nonlinear boundary value problem (BVP), we can obtain corresponding BVPs for the potentials at different orders. The first order diffraction velocity potential is relatively easy to obtain. The second order problem is complicated by the inhomogeneous forcing term in the free surface boundary condition, which is given in terms of quadratic products of the first order potential:

$$Q=\left[-\frac{i\omega}{2g}\phi^{(1)}\left(-\omega^2\frac{\partial\phi^{(1)}}{\partial z}+g\frac{\partial^2\phi^{(1)}}{\partial z^2}\right)+i\omega\left(\nabla\phi^{(1)}\right)^2\right]_{z=0}-Q_I \tag{1}$$

where Q_I represents the contribution from quadratic products of the first order incident potential itself and it is subtracted out owing to the free surface condition satisfied by the second order incident potential. $v=\omega^2/g$ is the infinite-depth wavenumber and g is gravity. In addition, the potential must satisfy the condition on the fixed body surface S_b and the seabed S_d, and the radiation condition at infinity.

The first order and the second order boundary value problems can be solved by the boundary integral equation formulated by applying