International Journal of Offshore and Polar Engineering
Vol. 13, No. 3, September 2003 (ISSN 1053-5381)

Wave Drift Force and Moment Acting on a Very Large Floating Structure of Arbitrary Geometry

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ABSTRACT

We applied the ray theory to estimating the hydroelastic behavior of VLFS since the method is easy to handle and not time-consuming. The theory itself is based on the classical ray theory. The hydroelastic behavior of VLFS is treated as wave propagation in the platform. The parabolic approximation is applied to smooth out the vertical elevation of the platform. Simple formulas for estimating the steady drift force and moment are derived. By employing these formulas and the ray theory, a quick computer code for estimating the steady drift force and moment acting on VLFS is developed. Some numerical results demonstrate the accuracy of this code, and the influence of nonuniform rigidity of the structure for the 5000-m-class floating airport is discussed.

INTRODUCTION

A Very Large Floating Structure (VLFS) concept has been offered at the Mega-Float project in Japan that has a mat-like thin configuration while the horizontal scale is very large. Among those who developed several computer codes to estimate the motion of VLFS are Seto and Ochi (1998). Their code can deal with the structure's arbitrary shape and the topology of the sea bottom, but the code is time-consuming and not useful for conceptual design, because VLFS designers want to test a variety of structure designs with many wave inputs, such as the period, wavelength, direction and so on. For their conceptual design, the designers also need to know the effects from all environments, such as bottom topology, breakwater, structure geometry and so on. This means that the method should be easy to handle and not be time-consuming.

With these needs in mind, Takagi and Kohara (1999) proposed an application of the ray theory to the hydroelastic behavior of VLFS. The theory itself is based on the classical ray theory, in which they used the behavior of VLFS—the motion can be regarded as wave propagation in the platform—and employed an assumption that the wavelength is very short compared with the horizontal size of VLFS. The classical ray theory insists that the wave field in and around the platform is represented as a summation of wave rays. This is the great advantage of the ray theory, because the 3-dimensional hydroelastic problem can be reduced to the 2-dimensional one. Thus, the computational scheme is very simple and not time-consuming.

Takagi and Nagayasu (2001) improved the previous ray theory in 2 ways. The shortcoming of the conventional ray theory is that the wave amplitude is suddenly changed along a ray that passes through a corner. This shortcoming is overcome by applying the parabolic approximation discussed by Takagi (2001). This is the first improvement. The second is their extension of the computer code so it is applicable for arbitrary bottom, environmental and body geometry. Using this method, they demonstrated the influence of bottom topology and of the structure's nonuniform rigidity, and several interesting shapes of the structure are offered to diminish the motion of VLFS.

Nanba et al. (2000) carried out a measurement of the steady drift force acting on an experimental VLFS model. They also performed numerical calculations on the steady drift force acting on VLFS. In the same paper, they showed a simple formula for evaluation of the steady drift force that requires only a line integral of relative wave elevation around the platform. In this paper, we apply the ray theory to the evaluation of relative wave elevation for this formula, and a similar formula for the evaluation of steady drift moment is derived under the assumption of a very short wavelength. Some numerical results demonstrate the ability of the ray theory to estimate the steady drift force and moment acting on VLFS.

FORMULATION

Ray Theory

The ray theory is widely used to estimate the distribution of wave amplitude in the region of arbitrary bottom topology. In this work, the standard procedure of the ray theory is applied. The only difference is the dispersion relation of waves in the platform. The outline of the theory is described here, and the details are found in Takagi and Kohara (1999).

Dispersion relation in platform. Suppose a flat floating platform of draft d ($d = 1 \sim 2$ m in Mega-Float project) located in the x-y plane, which coincides with the still water surface.

Following previous studies, the assumption of $d/\lambda \ll 1$ is applied where λ denotes the wavelength of incident waves. Since the motion of the fluid is supposed to be inviscid, irrotational and incompressible, the velocity potential Φ satisfying Laplace's equation is introduced. A further assumption is that the motion is sinusoidal with the angular frequency ω and the velocity potential is defined as the real part of $\Phi(x, y, z)e^{i\omega t}$.

Thin elastic plate theory gives the equation of the vertical displacement ζ of the platform:

$$D\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)^2\zeta+\rho g\zeta+i\rho\omega\Phi(x, y, 0)=0, \tag{1}$$

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Received July 15, 2002; revised manuscript received by the editors May 12, 2003. The original version (prior to the final revised manuscript) was presented at the 12th International Offshore and Polar Engineering Conference (ISOPE-2002), Kyushu, Japan, May 26–31, 2002.

KEY WORDS: VLFS, ray theory, parabolic approximation, steady drift force, steady drift moment.