Wave-Free Heaving Body Forms in Shallow Water

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ABSTRACT

Wave-free floating body forms in shallow water are studied using a wave-free singularity that is made by a source and vertical dipole combination to generate bulbous-shaped two- and three-dimensional bodies. The wave-free floating body is free from wave exciting vertical force in waves, which is equal to having zero radiation damping in heaving oscillation in calm water.

Shallow water effects on the body form appear to make the body more slender as the water becomes shallow. Wave exciting forces of the thus obtained body are calculated by the singularity distribution method to verify the wave-free characteristics at the designed wave-number. Variations of body forms in water depths are presented graphically in two-dimensional and axisymmetric problems.

Experiments are conducted for the models obtained theoretically and the results are discussed in comparison with the theory. They generally agree with the theoretical predictions.

KEY WORDS: Wave-Free Singularity, Wave-Free Body, Zero Radiation Damping, Shallow Water, Vertical Wave Force

1 INTRODUCTION

The "wave-free" characteristic of an offshore structure such as a column-footing type or a semi-submersible type is defined as that when the vertical wave exciting force acting on it becomes zero at a certain wave frequency. It is very useful and commonly used for designing an offshore structure having superior motion characteristics in waves. This characteristic was originally known as "the wave-free theory" by Bessho(1961). He obtained theoretical body forms using the wave-free singularities. Some practical bulbous forms are called "Motora form" proposed by Motora and Koyama(1961), and were confirmed through the model experiments.

As an extension of Bessho's theory, Kyozuka and Yoshida (1982) found body forms which become doubly or triply wave-free at a wave-free point. Yamaehita(1982) found body forms which become wave-free at two wave frequencies and confirmed them in experiments.

The approach using wave-free singularities has infinite variety because they can be linearly combined arbitrarily. They can be applied as one of the solution method of an "inverse problem".

The wave-free body forms have been known only in infinitely deep water, but are not known in shallow water. We therefore studied these forms in shallow water using wave-free singularity and conducted experiments on wave-free bodies obtained theoretically.

2 WAVE-FREE THEORY

Wave exciting forces/moments on a body in waves are obtained by the radiation wave height using the Haak-Krelation. We consider a body form which does not generate radiation waves in the far field in two- and three-dimensional radiation problems.

2.1 2-dimensional problem

Let us define the velocity potential of heaving oscillation as $\Phi(x, z, t)$ in Fig.1,

$$\Phi(x, z, t) = Re \{ \varphi(x, z)e^{i\omega t} \}$$  \hspace{1cm} (1)

where $\omega = 2\pi/T$: angular frequency of heaving oscillation

Velocity potential of the source at $(\xi, \zeta)$, is given by $\phi_S^D(x, y; \xi, \zeta)$ in the integral form as follows (Takahara(1976)):

$$\phi_s = \log \frac{r_1}{r_2} - 2P.V. \int_0^\infty e^{-kh} \frac{\sinh \kappa \sinh k\zeta}{k \cosh \kappa h} \cos k(x - \xi) dk$$

$$+ 2P.V. \int_0^\infty \frac{\cosh k(h - \xi) \cosh k(h - z)}{\cosh \kappa(h \cosh k h - k \sinh \kappa h)} \cos k(x - \xi) dk$$

$$+ 4\pi \frac{\cosh k_0(h - \xi) \cosh k_0(h - z)}{2k_0h + \sinh 2k_0h} \cos k_0(x - \xi)$$  \hspace{1cm} (2)