船舶在波浪中大幅度運動性能之研究(II)

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ABSTRACT

Based on Chapman's approach, a two and half dimensional method is introduced to study wave patterns due to large amplitude heaving motion of a three dimensional slender body with forward speed in waves. The governing equations are derived along characteristic lines. The forward speed effects are incorporated into the free surface and the body surface conditions.

The wave patterns and surface profiles of struts undergoing large amplitude heaving motion in still water and in waves with significant forward speed computed by the two and half dimensional method are shown.

Key Words: motion, wave pattern

摘 要

本計劃利用二維半方法探討細長體在波浪中高速前進，作大幅度起伏運動時，波浪變化情形. 控制方程式沿著特徵線推導，前進速度效應在自由液面以及物體表面皆考慮.

I. Introduction

Diffraction problem of ship motions with forward speed is a complicated one. Three dimensional approaches generally required large high speed computers, Chapman (1975, 1976), Yeung and Kim (1981), Yamasaki and Fujino (1985) and Faltinsen and Zhao (1991) developed two and half dimensional approaches to solve the ship-motion problems. The forward-speed effects on the free-surface were considered.

Based on Chapman's approach, Wang (1999a) and Wang et al. (1997a,b; 1999a,b) developed a two and half dimensional method to solve vertical hydrodynamic forces acting on three dimensional slender bodies with forward speed. This report intends to adapt the two and half dimensional approach to study wave patterns generated by struts with significant forward speed and large amplitude heaving motion in waves. The governing equations are derived along characteristic lines and the free surface flow problems are solved numerically. Finite fluid domain is taken for computation. Relaxed radiation conditions with numerical correcting terms are imposed on the open boundaries.

II. Governing Equations

For the present study, the ship hull is assumed to be slender. Diffraction problems of ship motions with significant forward speed are considered. Details are referred to Wang (1999b).

The free-surface boundary conditions along the characteristic lines are

$$\frac{\partial \zeta}{\partial s} = \frac{\partial \varphi}{\partial z_1} \quad on\, z_1 = \zeta, \bar{q} = \text{constant} \qquad (1)$$

$$\frac{\partial \varphi}{\partial s} + g\zeta = 0 \quad on\, z_1 = \zeta, \bar{q} = \text{constant} \qquad (2)$$

The body surface condition can be represented by

$$\frac{\partial \varphi}{\partial N} = -Un_1 \qquad (3)$$

where $\frac{\partial}{\partial N}$ means derivative along a unit vector N which is perpendicular to the contour of the body in a cross section. Positive direction of N is into the fluid domain. n_1 is the x_1 component unit normal vector.

III. Wave Pattern of Slender Bodies in Still Water

Faltinsen and Zhao used simplified theory to study unsteady wave elevation around a strut with parabolic water-plane area and wedgeshaped cross-sectional area in unsteady heave motion with forward speed. The water-plane surface is

$$\frac{2y_1}{B}=1-(1-2x_1/L)^2$$

The length of the strut was 1 m, the breadth 0.05 m and the draught was 0.2 m. The draught was constant along the whole length of the strut.

When the strut undergoes heaving motions

$$Z(t) = -Z_a \sin \omega t \quad (4)$$

where Z_a is the amplitude of pure heaving motion, and ω is the frequency of motion. The Froude number was 1.0 and the circular frequency of oscillation ω=8 rad/s. The amplitude of the wave elevation is shown in Fig. 1.

When the strut undergoes large amplitude heaving motion. The wetted surface between the strut and the fluid changes from time to time, yet Eq. (3) should be satisfied on the wetted surface as time varies. Eqs. (1) and (2) are solved on $z_1 = \zeta$. Starting initially from $z_1 = 0$, the wave generated by the forward oscillating motion of the strut is used as the new wave boundary condition. And the computation repeats. Figure 2 shows the computed wave pattern contours by using $\varphi_i = 0, F_n = 1.0$, Nx=20, Nt=49, Ng=20, Nr=10, Z_a=0.195m at time around Te/7. For the present computation, the computed wave profiles remain the same after the first iteration. The wave elevation shown is $\zeta / L * 100$, so 1.0 mark on the contour is roughly equivalent to 0.05 in Fig.1. Comparisons between the wave pattern computed at Te/7 as shown in Fig. 2 by the two and half dimensional method and the amplitude of the wave elevation by the simplified theory of Faltinsen and Zhao as shown in Fig. 1 seem to be good. Other detailed unsteady wave pattern analysis are referred to Wang (1999b)

IV. Wave Pattern of Slender Bodies in Waves

Slender Body with Fixed Sinkage

When the strut moves with fixed sinkage into head seas with wave of

$$\zeta = -a \sin(kx_1 - \omega_e t) \quad (5)$$

where $F_n = 1.0$, Nx=20, Nt=49, Ng=20, Nr=10, a =0.01m, Eqs. (1) and (2) are solved on $z_1 = \zeta$. Wave pattern generated (excluding incident wave) at t=0 is shown in Fig. 3. The wave pattern is about the same as time varies, and is similar to the case when the strut moves forward with small amplitude heaving motion into still water as shown in Figs.9-12 of Wang (1999b).

Slender body with Heaving Motion

When the strut undergoes large amplitude heaving motions of the form of Eq.(4) into waves of the form of Eq. (5). The heaving motion of the strut and the wave encountered are both of the form of negative sine curve. For $F_n = 1.0$, Nx=20, Nt=49, Ng=20, Nr=10, a =0.01m, Z_a=0.195m. Eqs. (1) and (2) are solved on $z_1 = \zeta$, wave pattern generated (excluding incident wave) at t=0 is shown in Fig.4. The wave pattern varies slowly as time varies.

However when the strut undergoes large amplitude heaving motions of the form of

$$Z(t) = Z_a \sin \omega\, t \quad (6)$$

into waves of the form of Eq. (5). The heaving motion of the strut and the wave encountered are of different signs. For $F_n = 1.0$, Nx=20, Nt=49, Ng=20, Nr=10, a =0.01m, Z_a=0.195m. Eqs. (1) and (2) are solved on $z_1 = \zeta$.Wave patterns generated (excluding incident wave) at t=0 and Te/4 are shown in Fig.5-6. Since the strut moves upward into a decreasing wave, and downward into a rising wave. The wave patterns vary much faster as time varies. Detailed unsteady wave pattern analysis are referred to Wang (1999b)

Figures. 7-8 show the wave profile and wave pattern (excluding incident wave) around the strut heaving with large amplitude into waves at t=0. With $F_n = 1.0$, Nx=20, Nt=49, Ng=20, Nr=10, a=0.01m, Z_a = 0.195m, Eqs. (1) and (2) are solved on $z_1 = \zeta$. The wave patterns around the strut are computed all the way to the point five strut lengths behind the strut. Detailed unsteady wave pattern analysis are referred to Wang (1999b)

V. Conclusions

Based on Chapman's approach, a two and half dimensional method to calculate wave patterns of slender bodies with significant forward speed and large amplitude heaving motions is reported. The governing equations are derived along characteristic lines. The forward speed effects are incorporated into the free surface and body surface conditions. A more relaxed radiation condition introduced by

Yamasaki & Fujino (1985) is imposed on an artificial open boundary. With N_x and N_t properly chosen , the numerical scheme is stable for computing wave patterns for large amplitude heaving motions.

As an application of the method, in the present report, wave pattern around two struts are presented. They compare nicely with the computed results from other analytical approaches.

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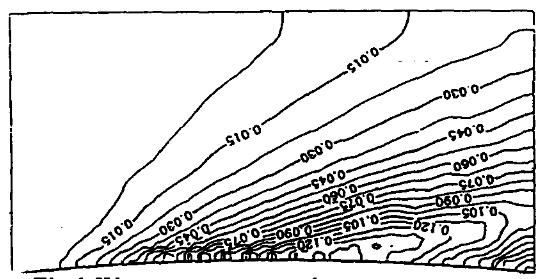

Fig.1 Wave pattern around a strut, Fn=1.0, ω =8/s [Faltinsen & Zhao]

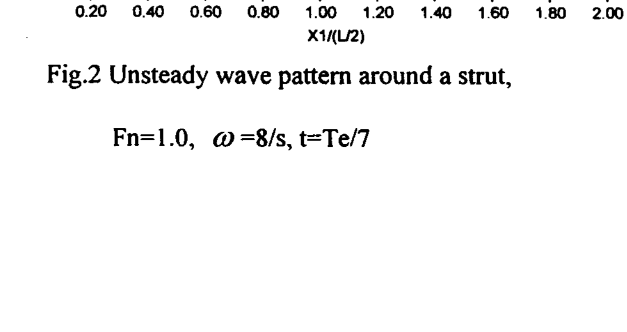

Fig.2 Unsteady wave pattern around a strut,

Fn=1.0, ω =8/s, t=Te/7

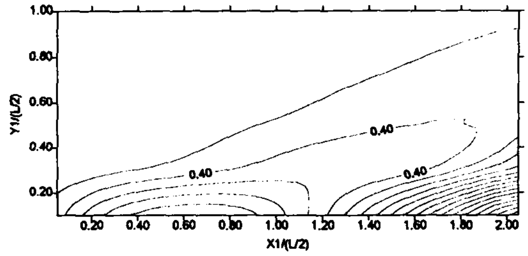

Fig.3 Unsteady wave pattern around a strut, Fn=1.0, t=0

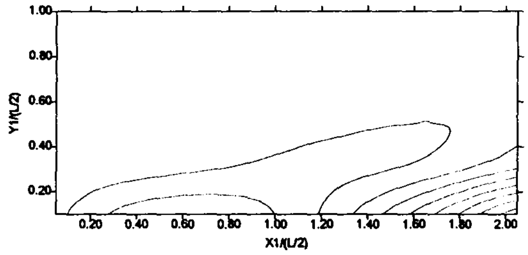

Fig.4 Unsteady wave pattern around a strut, Fn=1.0, t=0

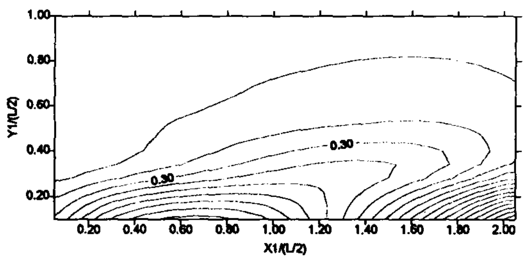

Fig.5 Unsteady wave pattern around a strut, Fn=1.0, t=0

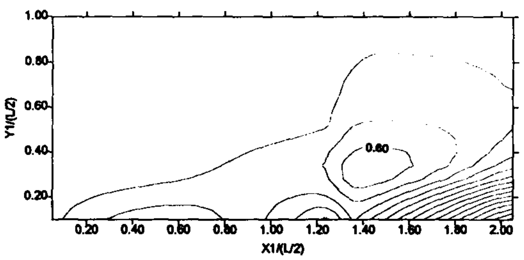

Fig.6 Unsteady wave pattern around a strut, Fn=1.0, t=Te/4

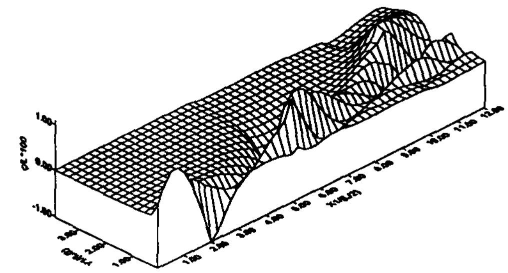

Fig.7 Wave profile around a strut, Fn=1.0, t=0

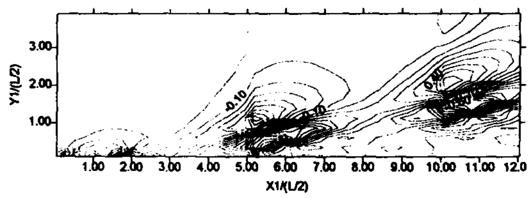

Fig.8 Wave pattern around a strut, Fn=1.0, t=0