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An Application of Fully Nonlinear Numerical Wave Tank to the Study of Chaotic Roll Motions

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ABSTRACT

A numerical wave tank is applied to the study of chaotic roll motions of a two-dimensional floating body. This numerical wave tank is constructed by a time-domain, fully nonlinear simulation method based on potential theory. In this simulation method, boundary value problems both on the velocity potential ϕ and its time derivative $\partial\phi/\partial t$ are solved. The coupling condition between wave and floating body is imposed as the implicit boundary condition of $\partial\phi/\partial t$ on a wet body surface. The radiation condition at the tank ends is satisfied by artificial damping technique. Using this numerical wave tank, the chaotic motions of a 2-D unstable floating body with a small negative GM are simulated in time domain taking fully nonlinear fluid-body interaction into account. The simulated time history, phase plot and Poincaré section of roll motions are presented and the dependency of the motion to wave height is discussed.

INTRODUCTION

For the analysis of chaotic roll motions, nonlinear ordinary differential equations of body motions are popularly used as model equations and hydrodynamic forces are taken into consideration as hydrodynamic coefficients, corresponding to the incident wave frequency, usually obtained by linear or weak nonlinear theories. However, for the analysis of chaotic motions, applicability of these coefficients is not self-evident. In the study of such a highly nonlinear hydrodynamic phenomenon, hydrodynamic coefficients, in other word hydrodynamic forces, should be treated as time-dependent variables.

The aim of this study is to introduce a technology to the field of nonlinear hydrodynamics and floating body dynamics. That is time-domain, fully nonlinear simulation. Time-domain, fully nonlinear simulation methods have been studied by Vinje and Brevig (1981), Cointe et al. (1990), Tanizawa (1990, 1995, 1996), Van Daalen (1993), Sen et al. (1989), Cao et al. (1994, Francescutto and Contento (1996) and others in the past decade, and fully nonlinear numerical wave tanks have been developed. Using these numerical wave tanks, nonlinear interaction between body motions and fluid motions can be solved in time domain without assuming any periodicity.

In our previous study (Tanizawa, 1997), we applied the numerical wave tank to the analysis of parametric roll motions of a bow section body and showed that the simulated harmonic and parametric motions, critical wave height of the parametric excitation, etc. agree well with the experimental data. In this study, we apply the same numerical wave tank to the analysis of chaotic roll motions.

SIMULATION OF CHAOTIC ROLL MOTIONS

Fully Nonlinear Numerical Wave Tank

Fig. 1 shows the configuration of the numerical wave tank used for the simulation. The ideal fluid domain is bounded by free surfaces, a piston wavemaker, bottom and rigid wall, and a floating body. The depth and length of the tank are taken as λ and 6λ, respectively, where λ is incident wave length. At both ends of the tank, damping zones are applied to avoid wave reflection. Inside the damping zone, damping terms are added to dynamic and kinematic free-surface boundary conditions to give an artificial damping effect to the free surface (Cointe et al., 1990). The length of the damping zones is taken as λ, therefore the effective length of the numerical wave tank is 4λ. The floating body is located in the middle of the tank and moored with weak spring and damper

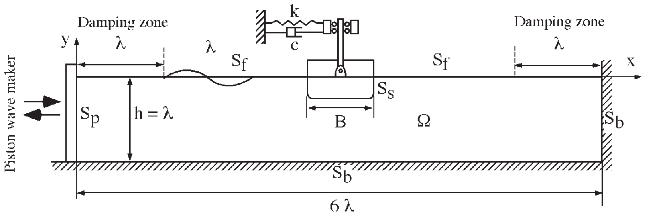

Fig. 1 Numerical wave tank

Floating Body			
Breadth	B	0.740	m
Depth	D	0.415	m
Draft	d	0.250	m
Weight	W	184.3	kg
Radius of inertia	R_I	0.266	m
Meta-center height	GM	–0.00043	m
Spring constant of mooring	k	51.07	N
Damping coef. of mooring	c	21.40	N/(m/s)

Table 1 Principal dimensions

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KEY WORDS: Numerical wave tank, fully nonlinear, chaos, roll motion, negative GM, parametric oscillation.