(Abstract for the 6th Symposium on Nonlinear and Free-Surface Flow, November 1998)

On the Accuracy of NWT for Radiation and Diffraction Problem

Katsuji TANIZAWA and Makiko MINAMI

Ship Research Institute, Shinkawa, Mitaka, Tokyo, Japan

1 Introduction

In the past decade, time domain fully nonlinear simulation methods were investigated by many researchers to study nonlinear floating body dynamics and wave loads. Also in SRI, one of the authors studied on the nonlinear simulation method, developed a two dimensional numerical wave tank (NWT) for seakeeping problems and showed application of NWT to various problems like large amplitude floating body motions, large amplitude interaction among floating body, incident wave and internal cargo fluid, parametric roll motions, chaotic roll motions, wave drift damping force, etc. [1, 2, 3]. Recently, in U.S.A and European countries, the target of research and development of NWT is shifted from two dimension to three dimension for practical use. Also in Japan, we should hurry up the development of three dimensional simulation codes.

Meanwhile, the accuracy check of NWT is important. One of the authors simulated two dimensional floating body motions in a closed tank and showed the simulated results well satisfy the conservation law of mass, momentum and energy [1]. Kashiwagi simulated the two dimensional radiation problems and showed the simulated hydrodynamic forces well agree with theoretical values and experimental data [4]. However, except these studies, few reports on close examination of the accuracy are published. Accordingly, as the next examination, we simulated the diffraction problem and the radiation-diffraction problem of two dimensional Lewis form body and compared the simulated results with theoretical values [5] and experimental data of Nojiri [6].

2 Outline of the Numerical Simulation

2.1 Numerical Wave Tank

Fig.1 shows the NWT used for the simulation. The length and the depth of the NWT are 6λ and λ respectively, where λ is wave length of the incident regular wave. Number of collocation points are 10 on both sides of NWT, 40 on the bottom, 120 on the free-surface and 34 on the floating body surface. The time step is set to $1/20$ of the incident wave period T_w . To compute wave heights of reflected and transmitted waves, free-surface elevation is computed at the fixed points $x = 1.9\lambda, 2.0\lambda$ and 4.0λ .

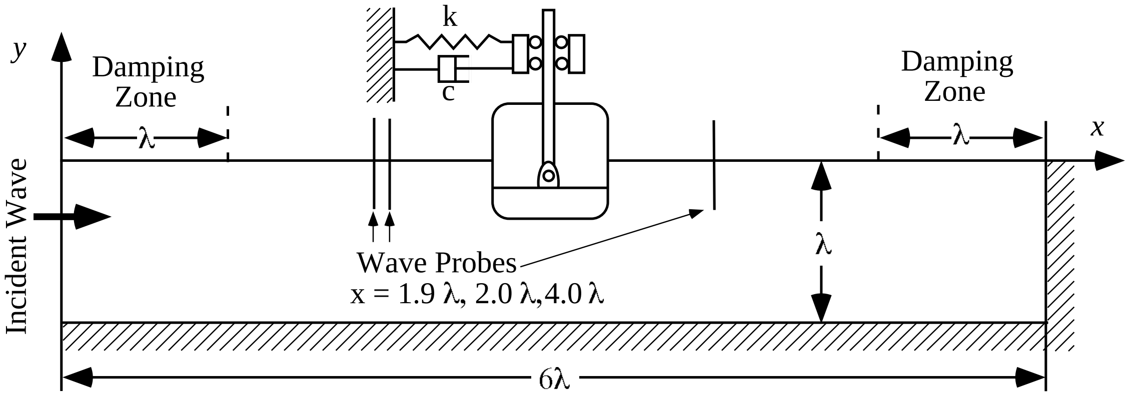


Fig.1 Numerical wave tank

2.2 Floating Body

To compare the simulated results with experimental data of Nojiri[6], we used the same Lewis form hull (Fig.2) and the same principle dimensions (Table 1) as the model used by Nojiri.

E-mail tanizawa@srimot.go.jp URL http://www.srimot.go.jp/dyn/waveload.html

Table 1 Principle Dimensions

Breadth	B	0.50	m
Draft	d	0.25	m
Displacement/Length	W	125.0	kg/m
Lewis Form parameter	H_0	1.00	
	σ	1.00	
Center of inertia	KG	0.135	m
Spring constant	k	197.58	N/m
Damping coefficient	c	19.80	N

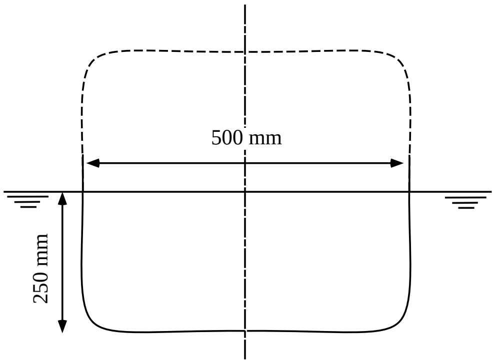


Fig.2 Floating Body

2.3 Incident Waves

Regular waves, nondimensional frequency $\xi_B(=\frac{\omega^2}{g}\frac{B}{2})$ ranged from 0.25 to 2.00 and wave height $H_I = 1cm$ and $7cm$, are used for the simulation.

Table 2 Incident Waves

		Wave Slope				Wave Slope	
ξ_B	λ	$H_I = 1.0$cm	$H_I = 7.0$cm	ξ_B	λ	$H_I = 1.0$cm	$H_I = 7.0$cm
0.25	6.283	1/628	1/90	0.75	2.094	1/209	1/30
0.50	3.142	1/314	1/45	1.00	1.571	1/157	1/22
0.55	2.856	1/286	1/41	1.25	1.257	1/126	1/18
0.60	2.618	1/262	1/37	1.50	1.047	1/105	1/15
0.65	2.417	1/242	1/35	1.75	0.898	1/90	1/13
0.70	2.244	1/224	1/32	2.00	0.785	1/79	1/11

3 Simulated Results

The diffraction problem of fix body and the radiation-diffraction problem of weakly moored floating body are simulated. The simulated results are presented in Fig.3 and Fig.4. The horizontal axis is nondimensional frequency and the vertical axis is also following nondimensional values.

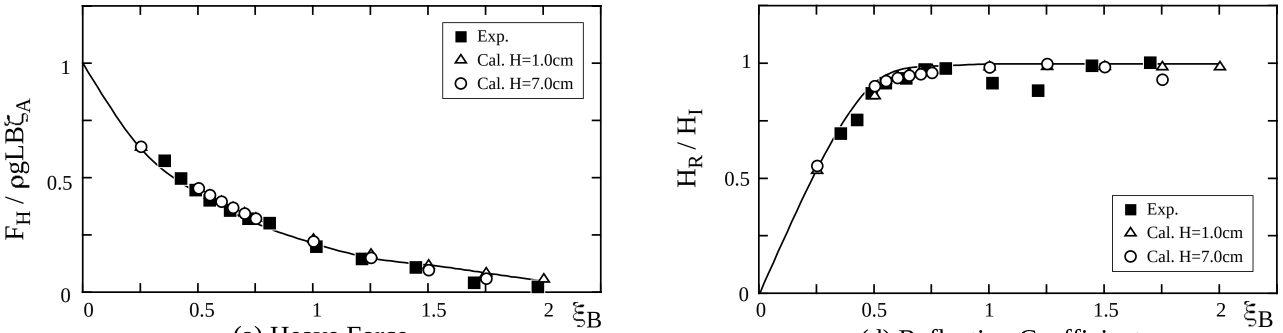
Sway force	;	$F_S/\rho gLd\zeta_A$	Sway amp.	;	X_A/ζ_A	Ref. coef.	;	$H_R/H_I(=\zeta_R/\zeta_A)$
Heave force	;	$F_H/\rho gLB\zeta_A$	Heave amp.	;	Y_A/ζ_A	Trans. coef.	;	$H_T/H_I(=\zeta_T/\zeta_A)$
Roll moment	;	$M_R/\rho gLBd\zeta_A$	Roll amp.	;	$\theta_A/k\zeta_A$	Drift force	;	$F_D/\frac{1}{2}\rho gL\zeta_A^2$

Where, L is length of the body and $\zeta_A(=H_I/2)$ is amplitude of the incident wave. Wave drift force is computed both from direct pressure integral on the wet body surface and wave transmission coefficient. For comparison, linear theoretical values and measured values by Nojiri are plotted.

3.1 Diffraction Problem

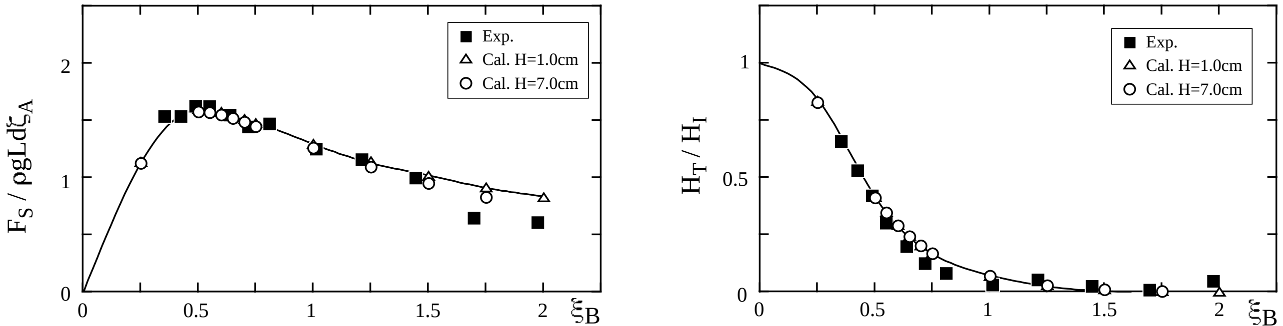
Fig.3(a) $\sim$ 3(c) shows wave exciting forces act on the fixed body. We can confirm in the figures that the simulated wave exciting forces for very small amplitude wave , $H_I = 1cm$, well agree with the theoretical values. As to $H_I = 7cm$, the simulated results still well agree with the linear theory in low frequency range. However, slight difference can be observed in high frequency range. The highest frequency for stable simulation is $\xi_B = 1.75$ and wave slope at this frequency is $1/13$. Even in such a steep wave, the difference between fully nonlinear simulation and linear theory is not so significant.

Fig.3(d) and Fig.3(e) shows reflection and transmission coefficient of the incident wave respectively. The simulated results also well agree with the linear theory in over all except high frequency range of $H_I = 7cm$. Fig.3(f) shows wave drift force acts on the fixed body. The wave drift force computed from reflection coefficient well agrees with theoretical value. On the other hand, agreement of the value obtained from the pressure integral is bad and the value for $H_I = 1cm$ is worse than that of for $H_I = 7cm$. The reason of this inaccuracy in not clear now.



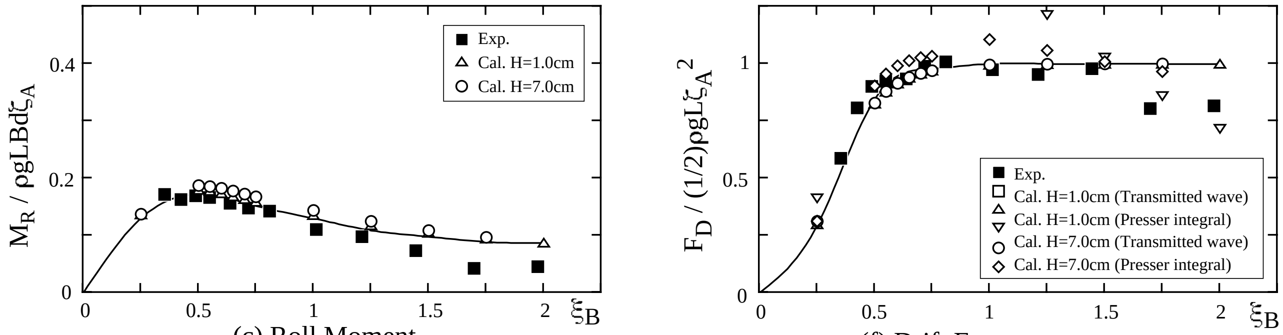
(a) Heave Force

(d) Reflection Coefficient



(b) Sway Force

(e) Transmission Coefficient



(c) Roll Moment

(f) Drift Force

Fig.3 Fixed Floating Body

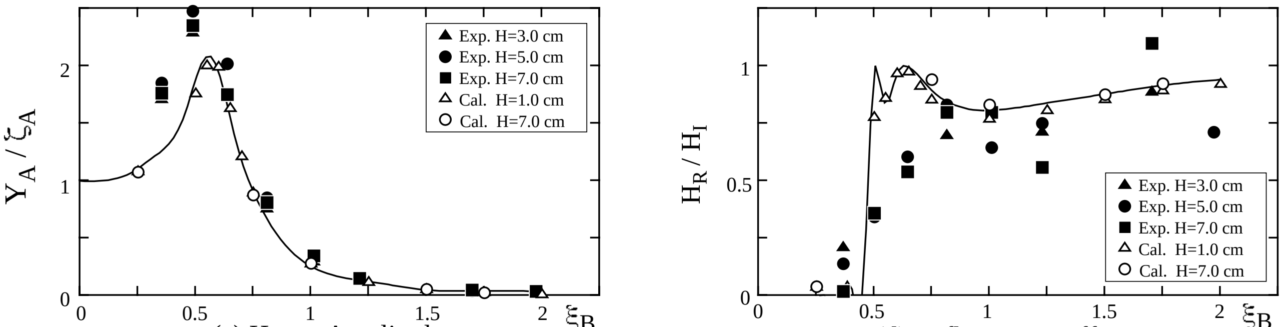
3.2 Radiation-Diffraction Problem

Fig.4(a) ~ 4(c) shows the amplitude of the floating body motions. Agreement of simulation and linear theory is good for both $H_I = 1cm$ and $7cm$. Near the resonant frequency of roll, simulated rsults for $H_I = 7cm$ are not plotted because the roll amplitudes are so large that simulations diverge.

Fig.4(d) and Fig.4(e) shows reflection and transmission coefficient of this radiation-diffraction problem. Also in these figures, the simulated values well agrees with the theoretical one. The wave drift force is plotted in Fig.4(f). Since the transmitted wave is very accurately simulated, the drift force computed from the transmitted wave agrees with the theoretical drift force. However, the pressure integral dose not give the accurate drift force neither for radiation-diffraction problem.

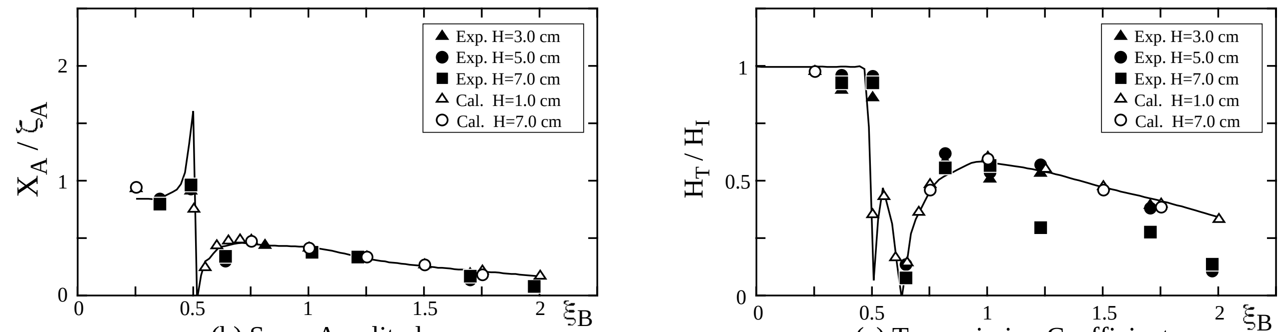
4 Conclusion

Through the series of simulations, we have confirmed that NWT simulates the diffraction and the radiation-diffraction problems accurately and obtained first order wave exiting forces and floating body motions well agree with theoretical values unless wave slope is too large. The obtained wave field is also accurate and agrees with theoretical value. As a result, the wave drift force obtained from wave reflection coefficient well agrees with theoretical value. However, the wave drift force obtained from pressure integral on the wet body surface is not accurate. For the study of nonlinear effects on the wave drift force,



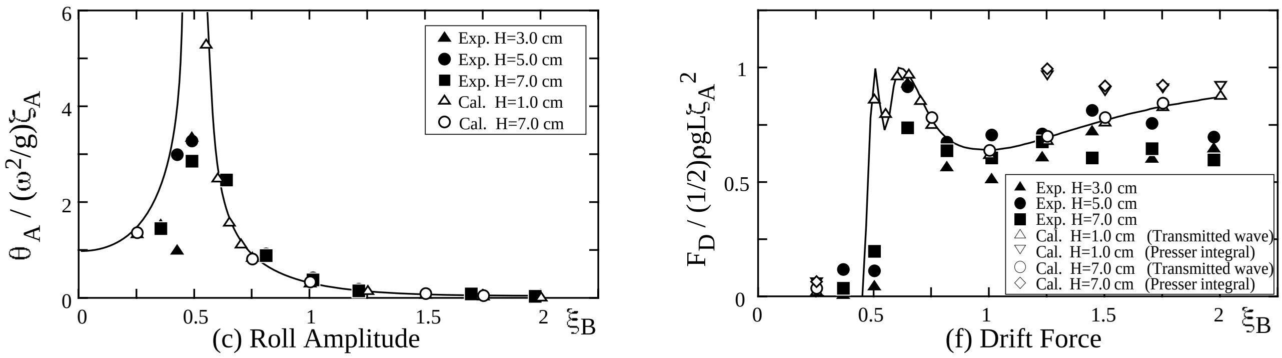
(a) Heave Amplitude

(d) Reflection Coefficient



(b) Sway Amplitude

(e) Transmission Coefficient



(c) Roll Amplitude

(f) Drift Force

Fig.4 Free Floating Body

pressure integral must be accurate enough for higher order wave forces. We are now seeking the reason of this discrepancy.

This study is a part of SRI's project research "On the drifting prevention of disabled ships in rough waves" supported by Ministry of Transport. Using NWT, effect of wave amplitude, water depth and geometry of the bottom to the wave drift force will be studied.

References

1) Tanizawa,K. : Nonlinear theory of wave-body interaction based on acceleration potential and its application to numerical simulation (in Japanese)*Ph.D thesis, Osaka Univ.*, (1997)
2) Tanizawa,K. : A study on parametric roll motions by fully nonlinear numerical wave tank, *Proc. of 8th ISOPE conference, Honolulu, Hawaii*, Vol.3, (1997)
3) Tanizawa,K. : An application of fully nonlinear numerical wave tank to the study on chaotic roll motions, *Proc. of 8th ISOPE conference, Montreal, Canada*, Vol.3, (1998)
4) Kashiwagi,M. : Full-nonlinear simulation of hydrodynamic forces on a Heaving two-dimensional body, *J. Soc. Nav. Arch. Japan*, Vol.180, (1996)
5) Maruo,H. : On the increase of the resistance of a ship in rough seas, *J. Zosen Kiokai*, Vol.108, (1960)
6) Nojiri,N. and Murayama,K. : A study on the drift force on two dimensional floating body in regular waves *Trans. West-Japan Soc. Nav. Arch.*, Vol.51, (1975)