Some topics for discussion on the numerical simulation of large amplitude floating body motions in ship stability problem

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1 Introduction

In the last decade, many researchers developed fully nonlinear numerical simulation methods to study large amplitude floating body motions in waves. These numerical simulation methods are generally called Numerical Wave Tank (NWT).

Two dimensional NWTs (2D-NWT) were firstly developed and variety of numerical techniques were examined using them. Now, the research of 2D potential flow NWT is almost finished and many good 2D-NWTs are available to simulate large amplitude floating body motions. We can apply them to study large amplitude responses, parametric resonances, chaotic responses and etc.

Three dimensional NWTs (3D-NWT) were secondly developed and still researchers are working on. One application of 3D-NWT is highly nonlinear wave load acts on vertical columns. Since higher order spectrum methods are not enough to capture steep wave run up on them, fully nonlinear NWTs are required. Three dimensional nonlinear wave interaction is also good application for oceanographers. For naval architects, 3D-NWT can be very attractive tool when floating body is supported. Practical 3D-NWTs are still under investigation.

Now, we are at a good timing to discuss on the application of NWTs to study stability of floating bodies in rough seas. This short article is written to offer some topics we should discuss when we apply NWTs to stability problems.

2 Topics

2.1 Accuracy of NWTs

NWT based on potential theory is known to be very accurate if they are correctly programed. Accuracy check of potential flow NWT is not the topic for discussion any more but for the topic of individual code test. Theoretical backbone of potential flow NWT is very solid. The interaction between floating body motions and ideal fluid motions is also well formulated in the acceleration field. Error due to numerical integration is small enough with correct treatment of singular point. We can say potential flow NWT is as accurate as classical frequency domain method. Tanizawa simulated motions of 2D midship section body in regular waves and compared simulated time histories with measurements [5]. (Fig.1) Kashiwagi simulated hydrodynamic force on 2D bodies by his 2D-NWT and showed the results well agreed with linear theory and experiment up to 3rd order [2]. Kashiwagi also simulated free motions of 2D bodies in regular waves and showed agreement between simulated motions and measured motions were quite good [3]. (Fig.2) Tanizawa proposed benchmark tests of 2D radiation and diffraction problems for ISOPE's NWT workshop and showed simulated results of 2D-NWTs well agreed with each other up to 3rd order, even if NWTs were developed independently by different researchers [7]. Taking the above arguments into account, I think potential flow NWT is accurate and practical tool for the estimation of floating body motions, except roll amplitude in resonant condition. Roll resonant problem is discussed in next section. One unsolved problem I have noticed is estimation of drift force by NWT. Wave drift force is the second order constant force and can be calculated both from wave field and direct pressure integral on wet body surface. Usually, drift force obtained from wave field agrees with experimental value well. However, drift force from direct pressure integral is not good. I think NWTs may have some problems only for the estimation of 2nd order constant component in hydrodynamic forces by direct pressure integral.

2.2 Viscous effects

For stability problems, viscous effect plays important role. In particular viscous damping is essential when we need accurate estimation of roll amplitude in resonant frequency. In potential flow NWTs, measured roll damping coefficient is used to correct the simulation if necessary. In principle, such a empiricism should be removed and viscous NWT should be applied for such a problem.

Analysis of parametric roll excitation is another problem we should consider viscosity. In this problem, critical wave height of Mathieu instability is the main concern. Tanizawa and Naito applied potential flow NWT to analyze the critical wave height for a bow section shaped 2D body and showed the obtained critical height by NWT is a little lower than experimental result [6]. (Fig.3) This difference is considered to come from viscous effect. Yeung and Liao developed FSRVM (Free surface random vortex method) [8] and successfully introduce viscous effect into potential flow NWT. They applied FSRVM to the analysis of Mathieu instability of a 2D body roll motion with and without bilge keel[9].

2.3 Numerical robustness

As we experience in many cases that free surface is not always stable everywhere but easily breaks locally. However, potential flow NWT assumes stable free surface and very weak against free surface breaking. This weakness limits the application of potential flow NWT. For analysis of damage stability, even if amplitude of wave and body motions are small, motion of shallow internal fluid is usually large and internal free surface is very unstable. To overcome this weak point, we don't need to use time consuming viscous NWT to entire computational domain but use it partially. Grilli combined BEM and VOF to simulate shoaling waves. [1]. Landrini developed gridless code SPlasH and analyzed wave pattern around a Wigley hull by BEM and post-breaking waves by SPlasH. [4] Such approaches are considered to be practical for me. For analysis of damage stability, potential flow NWT can be used to simulate ship and wave motions and viscous NWT can be use to simulate internal fluid motions.

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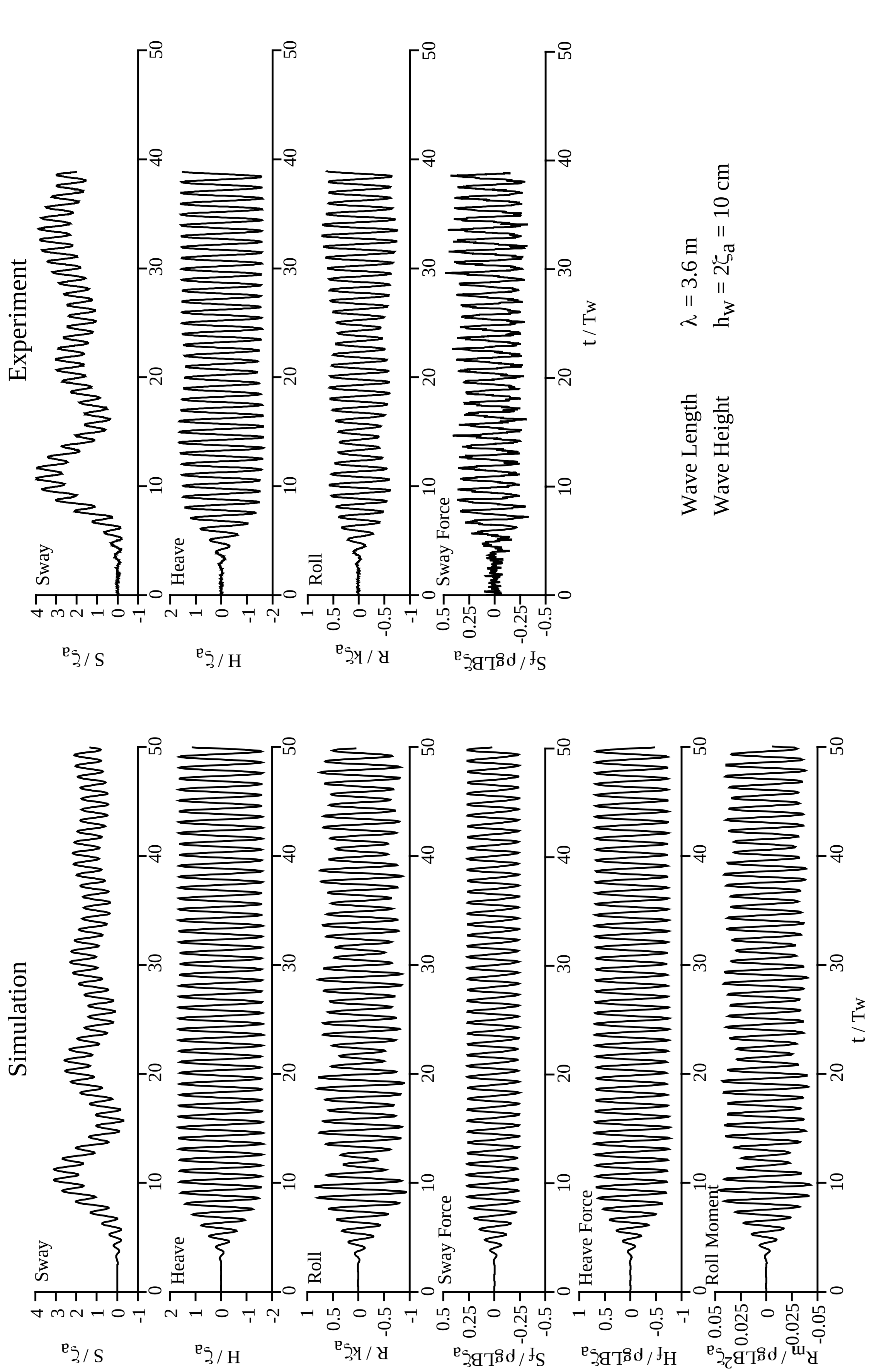

Fig.1 Comparison between simulated and measured body motions in a regular wave by Tanizawa

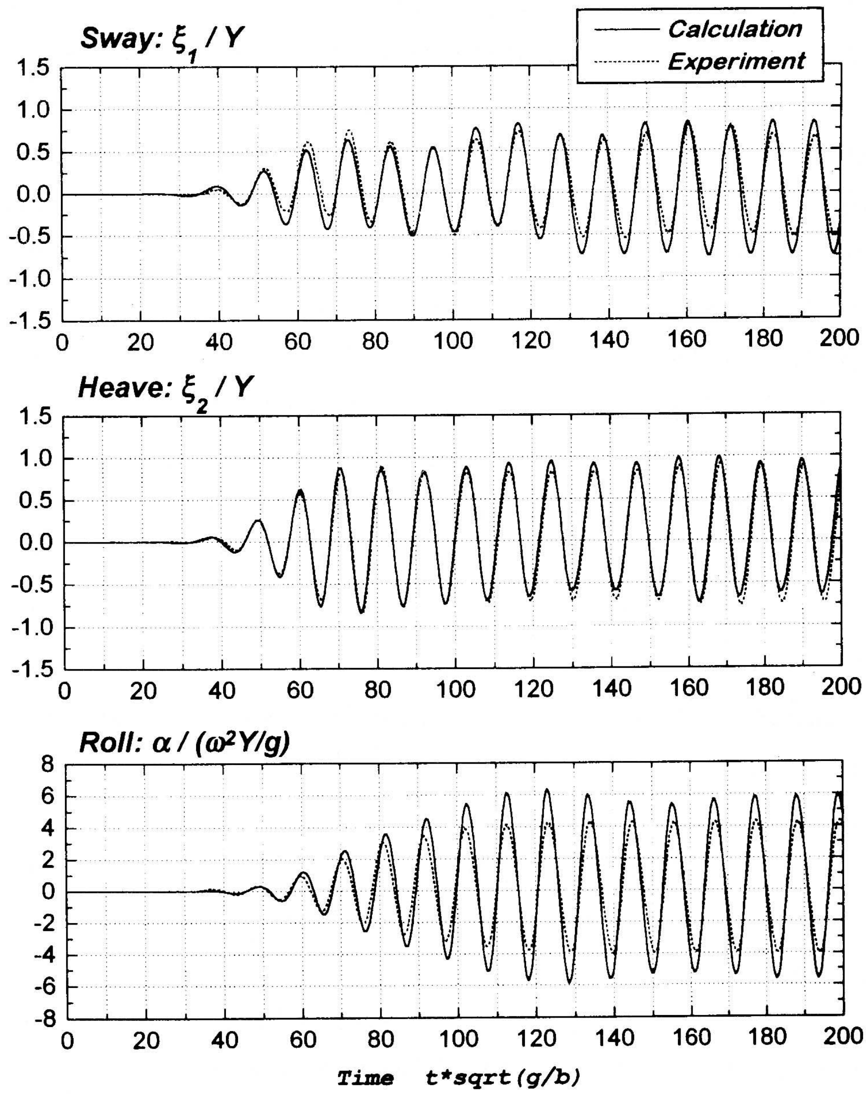

Fig.2 Comparison between simulated and measured body motions in a regular wave by Kashiwagi

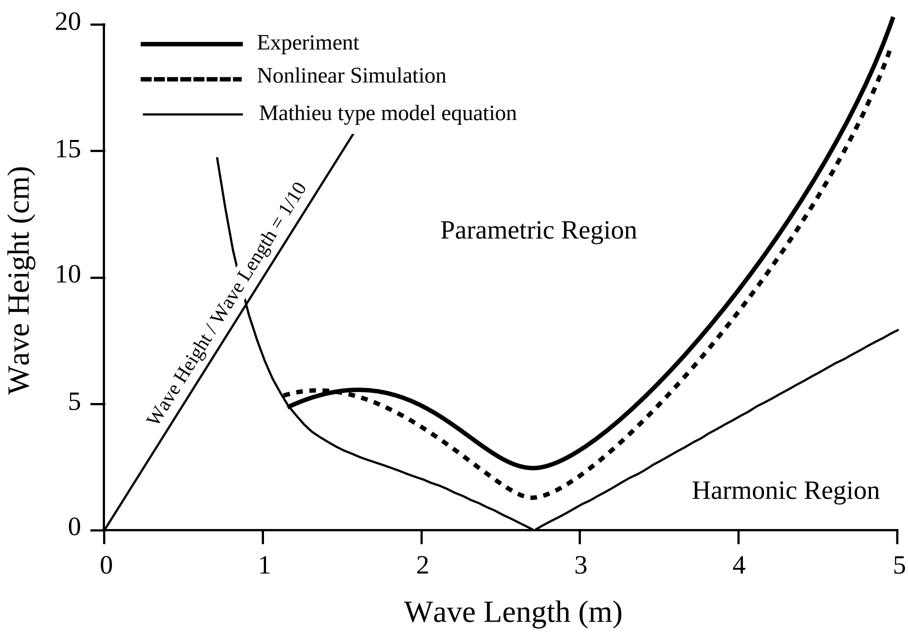

Fig.3 Critical wave height of Mathieu instability, Simulation and measurement.