Two-Dimensional Simulations of a Damaged Ship Using the MPS Method

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ABSTRACT
Recently, collision and grounding accidents of ships have been reported frequently. Since ships could have damage openings when these accidents occur, securing the survivability under flooded condition is required for ship design. Although the current SOLAS agreement guarantees ship safety under damaged condition, it just requires the survivability at the final equilibrium state. However, transient motions of a ship and floodwater, and dynamic coupling between them at an intermediate state are important for accurate capsizing/sinking prediction because these are highly nonlinear phenomena. Therefore, it is desired to develop numerical methods for ship motions and flooding simulation for damaged ships, which can take dynamic coupling between floodwater and ship motions into account. For this purpose, we try to develop the combined method in which hydrodynamic forces of intact parts are solved by the ordinary strip theory and those of damaged parts are done by the MPS method which is one of the particle methods. As a first step, we have investigated capability of the MPS method to time-to-flood simulations of a two-dimensional damaged ship by comparing the numerical results with the model experiments.

KEY WORDS: Damage stability, MPS method, damage opening, time-to-flood, two-dimensional simulation.

NOMENCLATURE
- $y_G$: horizontal displacement of the center of ship gravity
- $z_G$: vertical displacement of the center of ship gravity
- $\phi$: roll angle

INTRODUCTION
Several capsizing/sinking disasters of Ro-Ro vessels due to damage occurred in European waters in the 1980s. After these accidents, European countries strongly required IMO (International Maritime Organization) to revise the SOLAS (Safety of Life At Sea) agreement to enhance the damage stability of Ro-Ro vessels. As a result, the SOLAS90 standard was concluded. European countries had continued their activities to raise the safety level of damage stability. The tragedy of the Estonia of Ro-Ro car ferry in 1994 had led North West European nations adopted the Stockholm agreement as a regional standard. They had developed damage stability assessment methods of Ro-Ro vessels taking account of effects of water on car decks by means of theoretical approaches and physical model experiments.

Recently, there had been a lot of developments and achievements of numerical simulation methods for damage stability assessment through the HARDER (Harmonization of rules and design rationale) project. ITTC (International Towing Tank Conference) had conducted the benchmark tests of numerical simulation methods for damage stability assessment [A. Papanikolaou and D. Spanos, 2004]. Following the ITTC benchmark tests, further benchmark studies had been conducted within the SAFEDOR (Design, Operation and Regulation for Safety) project [ITTC Specialist committee on stability in waves, 2008]. These comparative studies demonstrated that numerical methods for quantitative assessment of the dynamic stability under damaged condition have not yet been established particularly for the prediction of the time until fully flooded (time-to-flood) or capsizing/sinking situations (time-to-capsize/sink), and further improvements are required for the overall performance. Therefore, advanced numerical simulation methods or codes for time-to-flood calculations are needed to develop more rational standard and to design real safety ships against damages due to collision and grounding accidents.

In numerical simulation of damaged ships, the behavior of accumulated floodwater in damaged compartments and the dynamic coupling