Dynamic Strength of a Ship Based on 2D Hydroelasto-plasticity and FEM in Extreme Waves

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ABSTRACT

Extreme waves have caused a lot of ship accidents and casualties in ocean. So nonlinear dynamic strength of a containership in extreme wave is studied, the dynamic ultimate strength and deformational angle at midship are paid a close attention. On one hand, traditional ultimate strength evaluation is mainly carried out in quasi-static assumption and no dynamic wave effect is considered. On another hand, dynamic response of ship induced by wave is studied on the basis of hydroelasticity theory so that no nonlinear ship structural response can be obtained in large waves. Therefore, the 2D hydroelasto-plasticity method which takes a account of the coupling between time-domain wave and nonlinear ship beam is proposed. This method combines hydroelasticity method with FEM to calculate wave load and nonlinear dynamic structural responses in extreme wave. In addition, nonlinear dynamic FEM is also applied for the nonlinear dynamic strength of a ship as it traverses in waves, while taking the especially nonlinear slamming force into consideration. However, nonlinear dynamic strength of ship in large waves is becoming a focal point to study for most ship mechanics researchers. Masaoka, et al. (2003) used a numerical approach for ship hull girder collapse behavior in wave, a structural analyzing system to investigate ship longitudinal collapse behavior is developed in this study, the system is a dynamic finite element system that considers the interaction between structural and hydrodynamic non-linearity, nonlinear hydrodynamic forces acting on the ship hulls are calculated by the Ursell-Tasai method. Iijima, et al. (2011) studied dynamic collapse behavior of a ship’s hull girder in waves, a simulation method is proposed firstly. Then a series of tank tests is conducted using the scaled model to validate the simulation results. Liu, et al. (2014) used a strip code to calculate the wave loads of containership when it traversed in extreme waves, and then these wave loads were applied on nonlinear dynamic FEM model to obtain nonlinear dynamic VBM and angles at midship. Liu, et al. (2014) proposed a hydroelasto-plastic method to evaluate ship nonlinear dynamic strength of ship beam in extreme waves, regarding ship structure as a pure elasto-plastic beam with sulciform section, no buckling effect of ship girder is considered while Liu, et al. (2015) considers the interaction and coupling between in ship structure and waves, a simplified progressive collapse method taking the buckling effect of ship structure into account is combined into the 2D hydroelasto-plasticity method.

Ship hydroelasticity is very complex problem in the case of container ships to analyze their structural response in waves especial for ultra-large container ships. Yamamoto, et al. (1978) proposed a time-domain 2D hydroelastic method to calculate the motions and longitudinal strength of a ship as it traverses in waves, while taking the especially nonlinear slamming force into consideration. However, nonlinear dynamic strength of ship in large waves is becoming a focal point to study for most ship mechanics researchers. Masaoka, et al. (2003) used a numerical approach for ship hull girder collapse behavior in wave, a structural analyzing system to investigate ship longitudinal collapse behavior is developed in this study, the system is a dynamic finite element system that considers the interaction between structural and hydrodynamic non-linearity, nonlinear hydrodynamic forces acting on the ship hulls are calculated by the Ursell-Tasai method. Iijima, et al. (2011) studied dynamic collapse behavior of a ship’s hull girder in waves, a simulation method is proposed firstly. Then a series of tank tests is conducted using the scaled model to validate the simulation results. Liu, et al. (2014) used a strip code to calculate the wave loads of containership when it traversed in extreme waves, and then these wave loads were applied on nonlinear dynamic FEM model to obtain nonlinear dynamic VBM and angles at midship. Liu, et al. (2014) proposed a hydroelasto-plastic method to evaluate ship nonlinear dynamic strength of ship beam in extreme waves, regarding ship structure as a pure elasto-plastic beam with sulciform section, no buckling effect of ship girder is considered while Liu, et al. (2015) considers the interaction and coupling between in ship structure and waves, a simplified progressive collapse method taking the buckling effect of ship structure into account is combined into the 2D hydroelasto-plasticity method.

INTRODUCTION

Extreme wave is more precisely defined as waves whose height is more than twice the significant wave height. Pelinovsky, et al. (2003) summarized large ship accidents around the world, at least 22 super-carriers were lost due to collisions with extreme waves from 1969–1994 in the Pacific and the Atlantic causing 525 fatalities. In addition to ocean freak wave record, Waseda, et al. (2005) simulated a tank freak wave to understand physical mechanisms and making method in laboratory tank, laboratory experiments are conducted to generate variety of extreme waves by both linear and nonlinear wave generation mechanisms.