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Computational and Experimental Studies on Parametric Roll of Containerships in Head Seas

Jin-Ho Yang[1)], Young-Woo Lee[1)] and Yonghwan Kim[2)]
[1)] Ocean Industry Research Department, Hyundai Heavy Industries, Co., Ltd.
Ulsan, Korea
[2)] Department of Naval Architecture and Ocean Engineering, Seoul National University
Seoul, Korea

ABSTRACT

Parametric roll resonance of modern containerships was predicted at initial design phase using numerical simulations and model scale experiments in a deep towing tank. Dynamic instabilities of modern containerships vulnerable to large but bounded roll motions when either floating or advancing in certain frequencies of wave encounter were successfully simulated using three-dimensional time-domain seakeeping computations based on Rankine source panel method. In the hydrodynamic computations geometric nonlinearity was accounted for in Froude-Krylov and restoring forces using simple wave corrections over exact wet hull surface of the containerships. The numerical simulations in the present work were compared with the calculations based on a classification society in-house code specially designed to assess parametric roll motions of commercial vessels. The computations for a mid-size and an ultra-large size containerships were validated through four degree-of-freedom model scale seakeeping experiments in regular head waves at the deep towing tank of Hyundai Heavy Industries.

INTRODUCTION

In general, the roll response is a matter of no great importance for the ship in head seas. However many shipping agents have reported excessive roll motions when containerships, whose ship shape and size are modern and large, were operating in head seas of the harsh ocean environments. The abrupt accident of the large containership as well as Panamax or post-Panamax class is well known (William et al., 2003; Riberiro e Silva et al., 2004). Recently, the concern for the roll resonance due to the parametric excitation in the head sea and following seas tends to increase with the size of the containership, which is now exceeding 10,000 TEU class.

The parametric resonance of the roll motion occurs suddenly in head seas or following seas and causes the roll motions to grow rapidly to an excessive roll angle of 40 degrees. In this situation, the kinematic energy delivered by the wave excitation to the pitch motion of the ship is partly transferred to the roll motion, so that the roll amplitude grows gradually while the pitch motion amplitude remains constant (Ribeiro e Silva et al., 2004).

The present study aims for the prediction of parametric roll resonance of modern containerships at initial design stage using a numerical method. There have been many theoretical and experimental studies on parametric roll resonance; Lee and Lee (2004), Lee et al. (2006), Bulian et al. (2006) and Shin et al. (2004). In this study, dynamic instabilities of modern containerships vulnerable to large but bounded roll motions when either floating or advancing in certain frequencies of wave encounter are simulated using three-dimensional time-domain seakeeping computations based on Rankine panel method recently developed in Joint Industry Project 'WISH' (Analysis of *W*ave-*I*nduced Nonlinear Loads and *SH*ip motions). In the hydrodynamic computations geometric nonlinearity was accounted for in Froude-Krylov and restoring forces using simple wave corrections over exact wet hull surface of the containerships. In this paper theoretical backgrounds and numerical techniques used in the WISH code are briefly introduced.

The numerical simulations of parametric roll motions using WISH code for a mid-size and an ultra-large size containerships were validated through four degree-of-freedom model scale seakeeping experiments in regular head waves at the deep towing tank of Hyundai Heavy Industries. The parametric roll resonance were generated when the transverse meta-centric height in the longitudinal seas varies periodically and when a wave encounter frequency is nearly twice of the roll natural frequency (Lee and Lee, 2004; Lee et al., 2006). A modern container ship with wide and flat stern and pronounced bow flare has been used in the experiments since operational casualties due to excessive roll motions have been often reported for this geometry of containerships. The model was restrained in sway and yaw motions, but free to surge, heave, roll and pitch motions.

NUMERICAL METHODLOGY

Linear Equation of Motion

In the present work, the infinite-frequency added mass of $M(\infty)$ was