Analysis of Linear and Nonlinear Structural Loads on a 6500 TEU Containership by a Time-Domain Rankine Panel Method

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ABSTRACT

Linear and nonlinear hull-girder loads on a modern 6500 TEU containership advancing in waves are calculated using a 3D time-domain Rankine panel method. The numerical code used is based on weakly-nonlinear scheme including nonlinear Froude-Krylov and restoring forces. Main focus of this study is to validate the nonlinear numerical code for industrial use through the comparison of the linear and nonlinear characteristics of wave-induced loads on a modern 6500 TEU containership with experiments. The compared responses include 6-DOF motions, vertical shear forces, vertical bending moments, torsion moments, horizontal shear forces and horizontal bending moments at high waves, as well as linear transfer functions.

KEY WORDS: 3D time-domain analysis; Rankine panel; Weakly-nonlinear analysis; Seakeeping analysis; Ship structural loads

INTRODUCTION

The main objective of this comparative study is the validation of a nonlinear 3D time-domain seakeeping code based on Rankine panel method. In general, the structural evaluation of designed ship is based on the specified rule values. However, those design wave loads are thought to be insufficient for large, fast and novel ships which are frequently introduced to the market at the present time. Consequently, recent interest in structural safety assessment for such modern ships has fueled the direct application of wave loads to structural FE (Finite Element) analysis. Hence, a 3D nonlinear time-domain Rankine panel method, WISH (Kim, K.H. et al. 2008; Kim, Y. et al., 2008), has been developed in a joint industry project, WISH-JIP.

Experimental tests with ship models carried out in seakeeping basin are used to predict the performance of new design of ships and to obtain data to validate numerical codes. The experimental investigations and validation of the numerical tools are also important part of the research issues. Verification, validation and accreditation are essential to the process for newly developed computer code to make successful debut in the support of design (Beak and Read, 2001). The experimental data for the newly designed containerships and passenger ships which have large flare on the bow and stern are limited. The majority of published previous experimental investigations on nonlinear ship motions and wave loads to validate seakeeping codes have been carried out for S-175 containership, Wigley hulls and virtual hull forms. O’Dea et al. (1992) presented nonlinearities in vertical motions (heave and pitch) and vertical accelerations of S-175 containership based on an experimental investigation using 1/50 model in head regular and irregular waves. To identify nonlinear effect on vertical motions several wave amplitudes at three wavelengths around the resonance frequency were investigated at two Froude number, 0.2 and 0.275. Adegeest (1995) presented results of towing tank experiments on the wave-induced loads in a hull cross-section in those conditions which introduce a nonlinear behavior for two Wigley hulls. The effects of bow geometry, forward speed and wave condition on the vertical hull girder loads, as well as heave and pitch motions, in head waves were investigated. Fonseca and Soares (2004a; 2004b) presented experimental results for ITTC S-175 containership in head regular and irregular waves using segmented 1/40 scale model connected by a rigid steel backbone. The model was towed by two vertical posts and the horizontal motions were restrained. In the experiment, heave, pitch and roll, vertical shear force and vertical bending moment were measured and collected at 50 Hz. The vertical loads were measured at midship and 1/4 Lpp aft from the forward perpendicular using strain gages. The objectives of the experiments were to investigate the influence of the wave steepness on the transfer functions, the higher-order harmonic amplitudes and the peak values of the vertical responses. The influence of the steady structural loads on the asymmetry of the vertical loads in waves was also investigated. The comparisons with numerical results from a nonlinear time-domain strip method also carried out.

To validate the class rules regarding design wave loads and numerical tools, a model test campaign for a 6500 TEU containership was carried out at WILS-JIP (Hong et al., 2008). Song et al. (2008) presented the comparison of linear motions and hull girder loads between the numerical results and the experiments carried out at WILS-JIP. In the present study, the linear and nonlinear motions and wave loads of the 6500 TEU containership are compared between numerical analysis carried out by using WISH and experimental results obtained by WILS-JIP.

The comparative study shows that the numerical results correspond