Semi-Empirical Assessment of Long-Term High-Frequency Hull Girder Response of Containerships

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High-frequency responses extracted from measurements onboard a Panamax containership and a post-Panamax containership were assessed by calculating cumulative fatigue damage. Responses were superimposed on damage obtained from numerical rigid body seakeeping calculations. Numerical analyses accounted for duration of measured seaways, ship headings relative to prevailing directions of encountered seaways, and ship forward speeds. Only the post-Panamax containership on its Far East route encountered relatively mild seaways, resulting in relatively low damage ratios. To represent worldwide service routes, measured high-frequency contributions were extrapolated to obtain high-frequency response of both these ships operating in severe North Atlantic and North Pacific seaways.

INTRODUCTION

Two recently conducted measurement campaigns extending over three years onboard a Panamax containership and over one year and four months onboard a post-Panamax containership revealed that high-frequency contributions under conditions leading to springing and whipping significantly increased global hull girder loads (Kahl and Menzel, 2008; Kahl et al., 2009). Other such measurements of Storhaug and Moe (2007) and Okada et al. (2006), for example, arrived at similar conclusions. Based on measured spectra, the contribution of high-frequency hull girder vibrations on fatigue damage was assessed by calculating cumulative damages, indicating their significant influence. The presented effects of high-frequency ship response have not yet been explicitly incorporated in strength-related design rules, because various uncertainties must be clarified before present design rules can be changed (Rathje et al., 2012). In addition, numerical methods still need to be validated before they can be used to obtain reliable predictions (Oberhagemann and el Moctar, 2011). However, the greater flexibility of modern ship designs calls for a practical technique to assess high-frequency response. The semi-empirical technique proposed here is an attempt to assess long-term high-frequency hull girder response based on numerical seakeeping computations and full-scale measurements.

A modified stochastic/probabilistic analysis method predicted global long-term, wave-induced hull girder vertical bending moments for the two containerships in random seas (see Guedes Soares and Schellin, 1995; 1998) and Rathje et al. (2000). The method relies on nonlinear wave-induced load effects—specifically, the use of an ensemble of transfer functions that are valid only for a certain range of wave heights. These so-called (nonlinear) pseudo transfer functions were obtained by nonlinear early correcting linear transfer functions to account for the non-vertical sides of these ships. Their hull shapes are characterized by extreme bow flare and stern overhang, a design feature that significantly increases the ships’ container deck carrying capacity.

First, rigid body seakeeping calculations were performed for both ships, using the frequency-domain boundary element code GL-PANEL (Papanikolaou and Schellin, 1992) to obtain transfer functions of wave-induced ship motions, accelerations, and vertical hull girder bending moments needed for the long-term analysis of the ships’ response in natural seaways. Then, the high-frequency hull girder response extracted from measurements was superimposed. For these numerical analyses, three aspects were found to significantly influence results. First, all seaways encountered during the voyage had to be individually considered. Second, the ships’ headings relative to the principle directions of encountered seaways had to be realistically estimated. Third, the ships’ forward speed was taken from shipboard recorded data.

Unfortunately, routes traveled by the post-Panamax containership during the Far East measurement campaign were characterized by relatively mild seaways, a situation that was reflected by relatively low damage ratios. To represent typical worldwide service routes, these measured high-frequency contributions were utilized to extrapolate high-frequency response of this ship operating in severe seaways occurring in the North Atlantic and/or the North Pacific. Thus, the resulting damage ratios were based on the assumption that this extrapolation procedure is valid also for more severe seaways. Although this assumption has not been validated for this ship, the resulting damage ratios seemed to reflect realistic values for such ships in worldwide service. Therefore, measurement campaigns onboard such ships sailing in severe seaways characteristic of the North Atlantic and/or the North Pacific are urgently needed to validate the proposed procedure.

MEASUREMENT ARRANGEMENT

Full-scale measurement campaigns were recently conducted onboard a Panamax containership and a post-Panamax containership to gather long-term data of wave-induced hull girder strains. Table 1 lists main particulars of these ships as well as the lowest hull girder natural frequencies for torsion and vertical bending modes. The campaigns were meant to consolidate current