International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 29, No. 1, March 2019, pp. 85–96; https://doi.org/10.17736/ijope.2019.ty03

http://www.isope.org/publications/publications.htm

Key Influencing Factors in Ultimate Strength Analysis for Large Container Ships

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Considering usual computation efforts, single-frame models are used in the ultimate strength analyses of container ships. However, the case of large container ships is more complicated, and further investigations should be made. Generally speaking, the modeling extent, boundary conditions, lateral pressure, and initial deflection are key factors in the ultimate strength analysis. As a case study, we investigated their influences on ultimate strength under both vertical bending and torsion cases for a typical 10,000 twenty-foot equivalent unit (TEU) container ship, and also bending–torsion interactions. The results are representative and can be reference values for container ships of similar sizes.

INTRODUCTION

Container ships are getting larger, and their structural strengths are major concerns for their owners and designers, especially after the 2013 crash of the *MOL Comfort*, an 8,110 twenty-foot equivalent unit (TEU) container ship. According to technical investigations (ClassNK, 2014), the local deformations of local structures such as double bottom are not negligible, which, however, has not been systematically considered previously. Thus, further investigations of large container ships to better understand their specific structural behaviors are meaningful.

Container ships that have large deck openings are subjected to both bending and torsional moments, and their structural strength is always an important topic. The past decade has seen many such investigations. Paik et al. (2001) investigated the ultimate strength characteristics of a typical 4,300 TEU container ship under torsion, developed the interaction equations between vertical bending and torsional moments at ultimate strength, and finally concluded that the influence of torsion-induced warping stresses on the ultimate hull girder bending strength is small while torsion-induced shear stresses will, of course, reduce the ship hull ultimate bending strength. Wang et al. (2002) studied the longitudinal ultimate strengths of ships with damages due to grounding or collision accidents and derived analytical equations for the residual hull girder strength and verified with direct calculations of sample commercial ships including container ships, obviously beneficial for operations in cases of emergency. Iijima et al. (2004) proposed a practical method for torsional strength assessment of container ship structures employing the Rankine source method for estimation of wave loads on a container ship, conducted finite element (FE) analyses of the entire ship model under the estimated loads, and discussed the combination of stress components to estimate the total hull girder stress. Peschmann et al. (2009) studied the reliability of the hull girder of container vessels subjected to vertical bending. Zhang et al. (2013) investigated the ultimate strength of some river-sea container ships using Smith's method and also analyzed the effects of the floor spaces, the scantlings of the deck longitudinal, the thicknesses of the deck plating, and the sheer strakes on the ultimate loading capacity. Parunov et al. (2015) investigated the hull girder reliability of the *MSC Napoli* container ship at the time of the accident, and a probability of failure associated with sensitivity study was performed, and the uncertainty model of the basic random variables involved is consistent with a recent proposal of the International Maritime Organization (IMO, 2006). Tekgoz et al. (2015) studied the effects of the neutral axis movement, translation, and rotation of the midship section on the ultimate load carrying capacity of a container ship subjected to asymmetrical bending moment for an intact ship hull and compared the results by the Common Structural Rules, finite element method, and MARS2000 software. Liu et al. (2016) employed a two-dimensional (2D) hydro-elasto-plasticity method to study the nonlinear dynamic responses of a container ship in extreme waves. Mohammed et al. (2016) studied the design safety margin of a typical 10,000 TEU container ship, considering the combined effects of structural nonlinearities and steady-state wave-induced dynamic loads, where the design extreme values of principal global wave-induced load components and their combinations in irregular seaways had been predicted using a cross-spectral method together with short-term and long-term statistical formulations.

In this paper, we have investigated the ultimate strength of a typical 10,000 TEU container ship by using nonlinear finite element analysis (NFEA), and effects of key influencing factors such as structural modeling extent, boundary conditions, lateral pressure, and initial deflection are investigated. The interaction between hogging bending and torsional moments at ultimate strength is also studied. The results could be reference values for similarly large container ships.

ULTIMATE BENDING STRENGTH OF CONTAINER SHIP BY SMITH'S METHOD

On one hand, the container ship hull girder ultimate bending strength was investigated by using Smith's method as specified by IACS (2015). Smith's method is a simplified method of hull girder analysis wherein the progressive collapse and post-buckling behavior of structural elements making up a cross-section is calculated, and hence the progressive collapse of the hull girder can be accounted for. After the accident of the *MOL Comfort*, the IACS revised the Unified Requirements, in which the implementation of Smith's method is outlined in section S11A (IACS, 2015).

The ultimate strength analysis based on Smith's method as presented in this paper is performed strictly according to IACS (2015)

Received July 10, 2017; updated and further revised manuscript received by the editors June 4, 2018. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-seventh International Ocean and Polar Engineering Conference (ISOPE-2017), San Francisco, California, June 25–30, 2017.

KEY WORDS: Ultimate strength, large container ship, key influencing factors, bending and torsion.