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

Vol. 28, No. 1, March 2018, pp. 105–111; https://doi.org/10.17736/ijope.2018.ty02

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

Dynamic Ultimate Hull Girder Strength Analysis on a Container Ship under Impact Bending Moments

Bin Yang and De-yu Wang
State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University
Shanghai, China

In this paper, the dynamic ultimate hull girder strength analysis on a container ship subjected to impact bending moments was studied based on a 3-D nonlinear explicit finite element model (FEM). In general, the dynamic response of a container ship is studied by means of the hydroelasticity theory, so the nonlinear dynamic response of the hull girder cannot be considered. A nonlinear explicit finite element method can overcome this problem. First, a nonlinear finite element method is used to obtain ultimate strength and the nonlinear relationship between the bending moment and rotational angle of the hull girder, and the ultimate rotation (Ry_0) is used as a failure criterion to estimate the dynamic ultimate strength of the container ship under an impact bending moment. Then the impact bending moment is characterized as a sinusoidal pulse function, and the pulse duration and amplitude of the impact bending moment on the dynamic elastic-plastic response of the hull girder were estimated based on the nonlinear explicit finite element method. Some important conclusions can be obtained from this paper.

INTRODUCTION

The ultimate strength of ship hull girders has been studied by many scholars since the concept of ultimate strength was brought forward. According to the concept of ultimate strength, when the external moment loads are higher than the ultimate carrying capacity, the ship hull girder will collapse. After years of effort, several effective calculation methods of ultimate strength were proposed, which can be classified into the following categories: Caldwell's method (Caldwell, 1965), the nonlinear finite element method (Qi et al., 2005), the idealized structural unit method (Paik et al., 2006), and Smith's method (Smith, 1977). A common point for these methods is that external load is assumed to be static. In fact, a ship sailing on the ocean is usually subjected to still water bending moments, wave-induced bending moments, and slamming bending moments. The action time of the wave-induced bending moment is often much greater than the natural frequency of the hull girder, so the wave-induced bending moment can be assumed as quasi-static and is considered together with the still water bending moment. In terms of slamming bending moments, the action time is so short that it cannot be regarded as a quasi-static load. The amplitude of the slamming bending moment is usually very large and has the same order of magnitude as the static bending moment (Xu and Soares, 2013). It is well known that permanent deformation occurs not only under excess wave loads but also impact loads, though the impact loads' duration is short. According to Ochi's perspective, the slamming duration changes with ship length (Ochi and Motter, 1973) and cannot be considered as static. In extreme sea conditions, such as a freak wave environment (Clauss et al., 2009), the amplitude of the impact bending moment will be very large. So it is necessary to study the dynamic ultimate strength of a container ship subjected to impact bending moments.

Traditionally, the strength of ships against freak waves is assessed by means of an ultimate strength evaluation, assuming quasi-static conditions, but the nonlinear dynamic structural response of ships to freak waves should be considered as well. As for the dynamic ultimate strength of the hull girder, because of time-dependent load, the solution process is more complicated than that for static ultimate strength. In addition, some important characteristics should also be considered, such as the dynamic constitutive equation of the material and inertia effect. Some relevant research work has been performed, such as on the dynamic buckling of the rectangular plate and the stiffened plate subjected to an in-plane half-sine impact load (Yang and Wang, 2016, 2017), the buckling of thin plates and the stiffened plate with v-grooves under an axial impact load by moving mass (Chen et al., 2007; So and Chen, 2007), and a series of dynamic ultimate compressive strength tests carried out on ship plating under axial compressive loads by Paik and Thayamballi (2003), with different loading speeds. Srivastava et al. (2003) investigated the dynamic characteristics of stiffened plates subjected to nonuniform harmonic in-plane edge loading by using a finite element method. Xu and Soares (2013) conducted a series of numerical calculations of the load-displacement behavior of five specimens, and the calculated results show good correlations with the experimental results. Ji and Wang (2014) studied the influence of impact load shape on dynamic displacement response of an across-stiffened plate subjected to in-plane impact loads based on ABAQUS/Explicit finite element (FE) modeling code. The nonlinear dynamic buckling of rectangular plates considering initial imperfections subjected to various pulse functions with six different boundary conditions is investigated by Ramezannezhad et al. (2015).

However, research on the dynamic ultimate strength of the ship hull girders under impact bending moments is very rare. The ship will usually be subjected to sagging moments and hogging moments when navigating. However, in the present paper, only the dynamic ultimate strength of ship hull girder under a hogging impact bending moment was studied. Because the dynamic responses of ships under sagging and hogging moments are very similar, and the main difference is that the ultimate sagging strength is smaller than the ultimate hogging moment, it is therefore reasonable to study the dynamic response and ultimate strength of container ship subjected to hogging impact bending moments. First, the midship region of the 3,100 TEU container ship is used as a research object. A 3-D finite element (FE) model

Received March 24, 2017; revised manuscript received by the editors July 10, 2017. The original version was submitted directly to the Journal.
KEY WORDS: Dynamic ultimate strength, hull girder, container ship, impact bending moment, pulse duration.