Assessment of the Double-hull Side Structure Response in Severe Ship Collisions

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ABSTRACT

A collision or grounding event may lead to large plastic deformation and fracture in collided ship, which could result in severe consequences. Therefore, it is of great importance to predict the response of ship structures rapidly and accurately when subjected to impact loads. Numerical simulation and simplified analytical method are carried out to investigate their internal mechanics in two specific scenarios. Based on the deformation patterns observed in numerical simulation, analytical expressions for assessing the resistance of components such as plate, stiffener, web frame and web girder are established. Several assumptions are made to predict fracture. In combination of these individual members, curves of resistance force versus indentation are obtained, which correspond well with the results conducted by the numerical simulation.

KEY WORDS: Collision; double hull structures; simplified method; finite element simulation; resistance-displacement response

INTRODUCTION

Ship collision and grounding are accidents that will result in catastrophic consequences such as economic loss and potential ecological pollution. However, the collision scenarios which a ship may encounter are uncertain because of complicated navigation environment and diverse structural design of itself. Therefore, a fast and reliable procedure should be developed for the potential collision accidents forecast in the preliminary design.

According to Hong (2008), the prevailing approaches to assess the internal mechanics of ship collisions are experiments, numerical simulation and simplified analytical method. Among them, the full-scale collision and grounding experiments are too expensive to implement. While the model tests involve complex scaling effects and the process is lengthy for unexpected problems. Comparatively, numerical analysis gives priority to the experimental method due to its low cost and repeatable. Furthermore, it can provide satisfactory results including the deformation and fracture details as well as the resistance force. Therefore, it has been extensively treated as “numerical experiments”. For example, Haris and Amdahl (2013) used the software LS-DYNA to produce virtual experimental data for several ship collision scenarios evaluating the interaction between the deformation on the striking and the struck ships. Gao et al. (2014) took the numerical simulation to verify the accuracy of the proposed analytical method that can rapidly predict the response of FPSO side structures collided by rigid bulbous bow. Sun et al. (2015) conducted numerical analysis to validate the proposed analytical method that deals with double side structures collided by a raked bow. Liu and Soares (2016) provide analytical method to estimate the extent of structural damage within double-hull tanker side structures during minor head-on collision and it was validated by numerical simulation with precise modeling parameters confirmed by previous experimental results. However, the failure prediction of numerical simulation has not improved much because the commonly used failure stain is highly dependent on the element length-thickness ratio and the criteria for dealing with sheet metal ductile fracture beyond local necking is not well established. Thus, material failure should be validated against the experimental tests before performing structural analysis.

The simplified analytical method has been proved to be efficient and reasonably accurate for evaluating the crashworthiness of ship structures in preliminary design and structural optimization phases. Total resistance of structures is the sum of contributions of each individual component such as the web girders, the side plates, and the stiffeners attached to the shell plating. Analytical expressions for assessing them are numerous. Lately, Sun et al. (2015) demonstrated an analytical solution to assess the resistance of stiffened plate sustaining wedge-like bow collision. In particular, interaction law between the normal force and bending moment is considered in evaluating the effects of the stiffeners. Liu and Soares (2016) proposed a new simplified folding deformation model to assess the crushing force of girders with stiffened web subjected to local in-plane loads. As for the rupture of the side plate and the web girder, the commonly used criteria are the critical strain and the indentation depth, respectively. Beyond this point, a crushing model will switch to a tearing model derived by Ohtsubo and Wang (1995). In combination of these typical analytical solutions, the main features of the structural plastic deformation characteristics during impact can be revealed.

In this study, finite element analysis and simplified analytical method are united to investigate the crashworthiness of double hull ship structures withstandng collision or grounding by a wedge shaped object. Two typical collision scenarios are designed, based on the