Marine Structures 33 (2013) 188–213

Contents lists available at SciVerse ScienceDirect

Marine Structures

journal homepage: www.elsevier.com/locate/marstruc

Investigation on structural performance predictions of double-bottom tankers during shoal grounding accidents

Zhaolong Yu [a], Zhiqiang Hu [a,*], Jørgen Amdahl [b], Yi Liu [a]

[a] State Key Lab of Ocean Engineering, Shanghai Jiao Tong University, Shanghai 200240, China
[b] Department of Marine Technology, NTNU, Trondheim, Norway

ARTICLE INFO

Article history:
Received 23 August 2012
Received in revised form 20 May 2013
Accepted 29 June 2013

Keywords:
Shoal grounding
Analytical analysis
Smeared thickness method
Numerical simulation
Distortion energy
Resistance

ABSTRACT

An investigation is carried out in this paper for the predictions of structural performance of double-bottom tankers during ship grounding over the “shoal” type seabed obstacles. Hong and Amdahl developed a simplified analytical model for the unstiffened double bottom. This method is carefully studied, verified and then used as the first stage of our prediction. The second stage is concerned with stiffeners since stiffeners are indispensable components for double-bottom tankers. A prevailing way to handle is to smear stiffeners onto their attached plating known as the smeared thickness method. However, the effective ratio in this method is dubious in such shoal grounding accidents. Proper values of this parameter are determined in stage two, and then together with the method in stage one, constitute a reliable and efficient tool for structural performance predictions of double-bottom structures in shoal grounding accidents. A double-bottom tanker is chosen as object for the case study. Finite element models of the hold both stiffened and unstiffened are created for numerical simulations using the LS_DYNA software. Simulation cases cover a wide range of slope angles of the indenter and indentations. Numerical results show that Hong and Amdahl's model in stage one is capable of predicting energy dissipation with high precision but poor accuracy for grounding resistances, and a possible reason may be the neglect of vertical resistance. The updated smeared method proposed in stage two is also proved to be capable of grasping major characteristics of stiffeners. Results and conclusions drawn from this paper can be conveniently

* Corresponding author.
E-mail address: zhqhu@sjtu.edu.cn (Z. Hu).

http://dx.doi.org/10.1016/j.marstruc.2013.06.003

applied for assessments of the performance of ship double-bottom structures during shoal sliding grounding scenarios, and will benefit the application of accidental limit state design concept in the ship design stage.

1. Introduction

Although advanced navigational tools have been introduced to reduce the number of ship accidents, ship structures are still running the risk of exposure to accidental actions, such as collision and grounding, which may result in potential economic loss, severe environmental pollution and fatalities. The luxury liner Titanic, designed with the latest technology and engineered to be the largest and most luxurious steam ship in the world, was once proclaimed to unsinkable until it collided with the iceberg and sank on its maiden journal, which deprived of about 1500 people's lives. The grounding accident of Exxon Valdez in Alaska 1989 is considered one of the most devastating man-made environmental disasters ever to occur at sea. The accident resulted in the pouring of approximately 40,000 tons of oil into a pristine wilderness area, and it is now still suffering from adverse effects of the pollution [1]. These disasters caused great public sensations and more rational safety regulations for individual ships were demanded to enhance the sailing safety and protect the environment.

Typically, the prevailing approaches for analysis of crashworthiness can be divided into four categories, i.e. model scale tests, empirical methods, simplified analytical methods, and nonlinear finite element methods (NLFEM). Full-scale or large-scale collision and grounding experiments are seldom executed because they are usually too expensive and risky. Real accidents could be considered as large-scale "experiments". Investigations of real accidents are almost always of great value, providing essential insight into the governing physical deformation mechanism. Tabri et al. [2] used the results of a full-scale collision test in an inland river in the Netherlands to verify his analytical model, which accounts for the effects of sloshing on ship motion during a collision. However, too often researchers are not allowed to access ship yards for inspection of damaged ships. Small-scale tests may be difficult to interpret real events due to the intricate scaling laws involved. However, they can be used to verify analytical methods, though the costs are still high. NLFEM, which are considered as "numerical experiments", have exhibited great abilities to simulate certain grounding actions with the explosively increases of the computational capacity. Numerical simulations have the advantage of low costs, repeatable analyses, relatively short analysis periods, and are therefore widely used. For example, Simonsen et al. [3] employed the numerical simulation software LS_DYNA to verify a simplified damage prediction model for groundings. Alsos and Amdahl [4] investigated the failure criterions with respect to fracture with numerical analyses. Kitamura [5], Endo and Yamada [6] and Yamada and Endo [7] assessed a series of buffer-bow designs that were analyzed extensively with numerical simulation tools.

Additionally, compared with the empirical method for assessments of the high-energy collisions pioneered by Minorsky [8], the simplified analytical method is advanced because it is superior with respect to providing insight into the governing deformation processes; it is also mathematically tractable and predicts the response with reasonable accuracy and time efficiency. Many innovative simplified analytical methods have been developed over the past two decades. They are typically based on the reconstruction of realistic deformation mechanisms identified during actual ship accidents, model tests and numerical simulations. Wang and Ohtsubo [9] defined three major structural deformation modes: bending and crushing deformation of the transverse plate, folding of the plate behind the transverse plate, and tearing deformation of the plate far behind the transverse plate. Simonsen [10] developed a simplified analytical approach to calculate the structural resistance during raking grounding scenario, and assembled it into a comprehensive collision and grounding code DAMAGE, which considers both soft and hard grounding. Vaughan [11], Ohtsubo and Wang [12], Simonsen and Wierzbicki [13] have all developed different simplified analytical methods for assessing structural performance during ship grounding.