Marine Structures 44 (2015) 101–124

Contents lists available at ScienceDirect

Marine Structures

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

Probabilistic analysis of the hull-girder still water loads on a shuttle tanker in full load condition, for parametrically distributed collision damage spaces

J.M. Rodrigues, A.P. Teixeira [1], C. Guedes Soares [*, 2]

Centre for Marine Technology and Ocean Engineering (CENTEC), Instituto Superior Técnico, Universidade de Lisboa, Portugal

ARTICLE INFO

Article history:
Received 10 February 2015
Received in revised form 2 August 2015
Accepted 3 August 2015
Available online 4 September 2015

Keywords:
Flooding
Damaged ship
Loads

ABSTRACT

Box-shaped damage affected volumes are applied, with parametric variation of their positions and extensions, to an otherwise intact shuttle tanker in full load condition. The vessel's deadweight is numerically calculated and the lightweight is estimated using semi-empirical formulations to a great extent. For each damage configuration, the final position attained by the ship is investigated and the corresponding global loads are assessed, in terms of still water vertical bending moment and shear force. The ship is considered to be floating in the absence of waves and a quasi-static version of a generalized adaptive mesh pressure integration technique code, for progressive flooding of floating objects, is used to model the progression of the floodwater and the vessel's attitude. The probabilistic model suggested by the Marine Environment Protection Committee of the International Maritime Organization (MEPC-IMO) is considered for the collision induced probabilistic distribution of the damage boxes. A total of 90 damage cases are considered and comparisons of the maximum loads and the location where these take place is carried out relative to the intact case. The minimum design values for still water bending moment and shear force, included in the Common Structural Rules for Bulk Carriers and Tankers of the International Association of Classification Societies (IACS), are introduced in the analysis and their envelopes are

* Corresponding author. Tel.: +351 218 417 607.
E-mail address: c.guedes.soares@centec.tecnico.ulisboa.pt (C. Guedes Soares).
[1] Member ISSC2015 Committee IV.1 Design Principles and Criteria.
[2] Chairman ISSC2015.

http://dx.doi.org/10.1016/j.marstruc.2015.08.002
0951-8339/

compared with the numerically obtained values in light of a probabilistic assessment. Several conclusions are taken regarding the effects of the damage parameters variation, and important findings are presented specifically when accounting for the MEPC-IMO probabilistic distribution, in opposition to a uniform distribution of the damage cases.

1. Introduction

Although still relatively rare, several studies have been carried out in load assessment of damaged ships and consequent structural reliability analysis. Chan et al. [3] presented a time domain nonlinear code where outputs regarding the global wave loads were compared with previous experiments carried out in Ref. [2]. Folsø and Iaccarino [8] conducted a study where a set of forced heel angles are applied on a tanker, through mass manipulation, and their effect on the global hull girder loads is assessed. Later Korkut et al. [16], carried out experiments with a model of a Ro–ro ship, in which measurements of vertical shear force and bending moment were recorded and studied. Folsø et al. [7] further advanced their research by implementing an actual flooding of several compartments and assessing the effects of asymmetrical flooding; yet the effects of the flooded mass are but that of the addition of a static mass. Santos and Guedes Soares [26] presented a time domain model capable of computing the vertical shear force and vertical bending moment longitudinal distribution on ships subjected to progressive flooding, by further expanding their original method – its capabilities are comprehensively demonstrated in Refs. [24,25,28]. More recently [1], carried out benchmarking tests for a 1/100 scale model of the well-known US Navy Destroyer Hull 5145 in head and beam waves. Intact and damaged conditions were considered and results were compared with those predicted by a nonlinear time domain code. Lee et al. [17] have performed various experiments with a model of the same destroyer. A two dimensional linear method, capable of predicting the hydrodynamic loads on damaged ships, is also presented and results are compared with the experimental ones, where various damage conditions, with different hull openings and locations, are tested.

In all previous tests, benchmarking and code validation related motivations were the basis for decisions regarding the location, shape and extension of the damage cases considered. However, a new paradigm, embracing a general trend in engineering, known as Goal Based Standards (GBS), has been introduced by the International Maritime Organization (IMO), which relates to reliability of new ship structures. Under this approach, the emphasis is set on the demonstrated capacity of a given design to meet a specified degree of reliability, in contrast with traditional similar known-to-work based approaches. Particularly in what damage stability is concerned the previous approach, involving the consideration of a maximum damage length as a function of the ship subdivision index which would give the maximum permissible length of each compartment, has been replaced by a newer one. The new approach considers the product of the probability that each compartment, or group of compartments, may be flooded by the probability that the ship, in such condition, can survive. The sum of these products, for each damage condition, is required to be higher than the required subdivision index, which is a function of the length of the ship [27]. This change in paradigm was introduced already in the 89th Council Session of the IMO, in 2002, through a proposal by the Bahamas and Greece, but it was only in 2010 that the same council adopted it to enter into force in 2016 [13].

Under this new paradigm, similarly to pure damage stability related research, reliability studies involving the assessment of the hull girder ultimate resistance can be performed, taking into consideration probabilistic distributions of damage location, shape and extension, based on accidents historical data. Guedes Soares and Teixeira [9] is an example of a probabilistic load safety study regarding the intact ship, whereas Teixeira and Guedes Soares [30] present a review on the approaches that have been adopted to assess the implicit safety levels of both intact and damaged cases.

Prestileo et al. [20] expand the study of Ref. [21] where a case study is taken into consideration, corresponding to a particular flooding condition in a given location. The expansion is implemented by