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Bottom damage scenarios for the hull girder structural assessment

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ABSTRACT

This article covers the reliability assessment of the hull girder of a crude oil tanker, referring to a scenario in which the ship is exposed to sea loads after a damage to the bottom of the hull has occurred. A number of possible flooding configurations are examined, each one caused by a group of damage cases, characterized by different location and extent. Static loads, wave loads and residual structural resistance are determined for each damage case, with the objective of obtaining a prediction for the probability of the hull girder's failure. The various damage cases are compared to each other and unconditioned to derive the probability of failure extended to the ship's life due to a generic bottom damage.

A probabilistic Bayesian Network model has been created to deal with these variables and with the dependency relationships existing between them. The results provided by the model are analyzed with the aim of identifying the parameters most influencing the problem. The work is intended to contribute to the development of a more rational treatment of accidental conditions in design structural requirements for ships.

1. Introduction

A huge effort has been made in the last years by the International Maritime Organization (IMO) and the International Association of Classification Societies (IACS) to develop structural rules built on

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Goal-Based Standards (GBS) (see [1] for more details). This new approach, followed in other fields of engineering under the name of Performance Based Design (PBD), is based on the idea that design rules should not be intended to set prescriptive requirements or to give specific solutions, but they should rather set clear goals in terms of safety (see e.g. [2] for the formulation within IMO).

Such general goals are to be coherently reflected in a consistent framework of more specific functional under the name of Performance Based Design (PBD), is based on the idea that design rules should not be intended to set prescriptive requirements or to give specific solutions, but they should rather set clear goals in terms requirements and, in turn, of more specific provisions and standards by IMO, by classification society rules and by Administrations. Further, an important principle of PBD in general, and in particular of GBS in the marine field, is that it should be possible to seek the long term goals not only by compliance with published technical standards, but also by means of alternative solutions providing an equivalent level of safety [2].

Important elements in this PB oriented framework for design assessment are represented by the design scenarios, which are meant to convert the general goals and functional requirements expressed in terms of lifetime of the structure into a discrete set of representative situations where the assessment can actually be performed. The definition of Design Scenarios (DSs) is therefore a key point for demonstrating the compliance with the goal-based standards both of the specific requirements issued by the Administrations and of possible solutions provided by the designer as alternatives to those requirements.

In order to play this role, DSs need to be defined explicitly (i.e. they should cover all the aspects relevant to the assessment) and in such a way as to be actually representative of the structure's operational life.

Class rules for the main types of ships have been reformulated to comply with these new principles but, so far, only rules referring to intact conditions have been developed (see Refs. [3] and [4]). The scenario of the 'intact ship' is implicitly considered as the most probable and does not require further investigation for its selection among design scenarios. The characterisation of this scenario for the various types of structural checks has been progressively refined in the last decades and introduced explicitly in Rules in the most recent revisions, as remarked in [5].

In addition to that, it is explicitly foreseen in GBS (see [6]) that 'ships should be designed to have sufficient strength to withstand the wave and internal loads in specified damaged conditions' and that 'actual foreseeable scenarios should be investigated in this regard as far as is reasonably practicable'. The spectrum of possible damage scenarios is huge (including a huge number of damage typologies and of loading and environmental conditions with all combinations), so a 'pre-screening' of such scenarios is needed, based, as far as possible, on objective evaluations. The selection and characterisation of damage scenarios is not carried out in Rules and even in those sections where checks in damaged conditions are set, the definition of the background scenarios of such checks is not provided. As mentioned in [5], inconsistencies appear between similar verifications provided in [3] and [4] for the damaged hull girder strength verifications: for tankers wave loads are not considered, while for bulkers a fraction of the design vertical wave bending moment is included without explanations about the value.

In literature, the characterisation of design scenarios for ships in damaged conditions has been discussed e.g. by Teixeira and Guedes Soares [7] and Rizzuto et al. [8]. In particular in the latter paper a Bayesian Network (BN) model has been used to analyze a specific incident corresponding to a grounding event occurring in the hull bottom at mid-length of a tanker ship, creating an asymmetric flooding in a ballast tank located in that area. The specificity of the analysis developed in [8] did not allow any firm conclusion on the selection of a design scenario for grounding events, but the work identified a procedure for a consistent description of accidental scenarios and of the relationships linking together the strength and load variables describing the situation.

In the present paper, the same means (BNs) have been utilised on the same ship, but the object of analysis has been widened to include a much larger number of possible flooding configurations due to bottom damages, different sea conditions and the effects of both on different frames along the ship. This allows an evaluation of the relative importance of the various scenarios and provides input for the selection of representative design cases. The results of the study have been compared to statistical data available for incidents, but the most valuable information that can be derived from the analysis are to