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Hazard identification and scenario selection of ship grounding accidents

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ABSTRACT

The objectives of the present paper are to identify the hazard of ship grounding; where a ship runs on a rock with a forward speed, and to select a set of credible scenarios with a limited number that can still represent all possible situations of the accidents. For this purpose, the statistics of ship grounding accidents recorded by authorities for the period of 46 years during 1970–2016 are collated. An extensive analysis is undertaken to examine the statistical characteristics in association with random variables influencing the consequence of grounding. A total of six parameters, namely ship's forward speed, ship's trim angle, rock tip eccentricity, rock length, rock width and rock height are considered as random variables where the displacement or mass of the grounded ship is fixed. Each of the random variables is then formulated with a probability density function. A sampling technique is applied to the probabilistic selection of the grounding scenarios which are to be used for the consequence analysis within the framework of quantitative risk assessment. Important insights developed from the present study are discussed. Details of the analyses are documented.

1. Introduction

While in service, ships rarely are subjected to accidents which include grounding, collision, contact, fire, explosion, capsizing and hull girder collapse. Such accidents may result in catastrophic consequences associated with casualties, property damage and environmental pollution. Ship grouding studied in the present paper is one of the most frequent accidents in shipping. When large tankers are involved in a grounding event with breaching one or more cargo tanks, the environmental pollution due to an oil spill becomes a great concern. Fig. 1 shows the causes of oil spills with greater than 700 tonnes in amount occurred during 1970–2015 (ITOPF, 2016). It is seen from Fig. 1 that grounding accidents take up 33%. AGCS (2014) indicates that ship grounding takes up 50% of all marine insurance claims in excess of 1 m Euro during 2009–2013. Moreover, wreck removal costs can be several times larger than that of the hull value in some cases, because rescue and salvage operations are complex and costly as environmental concerns are raised. For example, the passenger vessel "*Costa Concordia*", which ran aground in 2012, significantly raised many issues to be resolved in the international marine salvage industry and caused new regulations to be set for improving safety performance in wreck removal operations (Senauth, 2013).

The International Maritime Organization (IMO, 2002) introduced a procedure for formal safety assessment (FSA) which is handy in identifying and evaluating risks to personnel, assets and the environment. The FSA procedure comprises five main steps as follows:

- Step 1: Hazard identification.
- Step 2: Risk analysis
- Step 3: Risk control options
- Step 4: Cost-benefit assessment
- Step 5: Decision making and recommendations

In step 1, all potential hazards leading to damages to personnel, asset and the environment are identified. The main result of this step is a list of hazards and associated scenarios which should be prioritized by identified risk level that should be the focus of a more thorough analysis in subsequent phases of the FSA. The accidental scenario identification and selection is the most vital stage of any risk assessment procedure or quantitative risk assessment and management (QRA&M), which affects all the following stages in the FSA framework.

Two available approaches can be used for the scenario identification stage; deterministic and probabilistic. In the deterministic procedure, a few scenarios are chosen by assuming a certain value for each scenario

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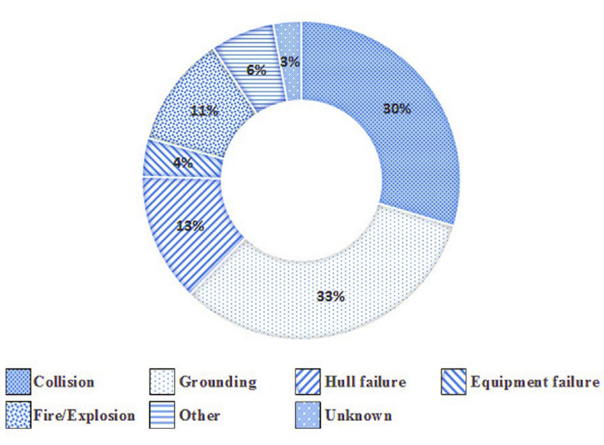

Fig. 1. Causes of oil spills with greater than 700 tonnes in amount for the period 1970–2015 (ITOPF, 2016).

parameter where the ship might be tested under one or more unfavorable accidental scenarios with a relatively low level of occurrence probability, leading to unfavorable consequences. On the other hand, the probabilistic approach identifies the hazards probabilistically with a set of scenarios in association with the random variables affecting the consequences of the accident (Paik and Thayamballi, 2007; Samuelides et al., 2009; Youssef et al., 2016). As ship grounding is rather uncertain and probabilistic in nature, probabilistic approaches are more desirable.

Numerous studies in the literature have used the deterministic approach to choose grounding scenarios, which were implemented in model tests and numerical simulations (Glykas and Das, 2001; Haris and Amdahl, 2012; Hong and Amdahl, 2008, 2012; Liu et al., 2015; Paik and Seo, 2007; Yu et al., 2013; Zeng et al., 2016; Zhang and Suzuki, 2006). In contrast, a few studies have used the probabilistic approach, in which each of grounding parameters has been dealt as a random variable by formulating a distribution function. Based on statistical data collected, Brown and Amrozowicz (1996) introduced a method to define probability density distributions for grounding damage extent as a function of a simplified set of independent variables circumscribing the ship structural design. This method is initially started by formulating probability density functions (pdf's) for ship speed, depth of water and obstruction characteristics. Similar work was conducted by Lützen and Simonsen (2003) where the grounding scenarios were described by pdfs for ship draught, speed and obstruction height, and width. Moreover, such analyses have also been performed by Rawson et al. (1998) and Tikka and Chen (2001). In recent years, the studies on the structural crashworthiness and also the response of post-grounding accidents are also found in the literature (Deeb et al., 2017; Hong and Amdahl, 2008; Khan and Das, 2008; Paik, 2007a, b; Samuelides, 2015; Zipfel and Lehmann, 2012).

In the light of the above discussion, this paper aims the way to select grounding scenarios using the probabilistic approaches. This method commences with collecting grounding accident database from different

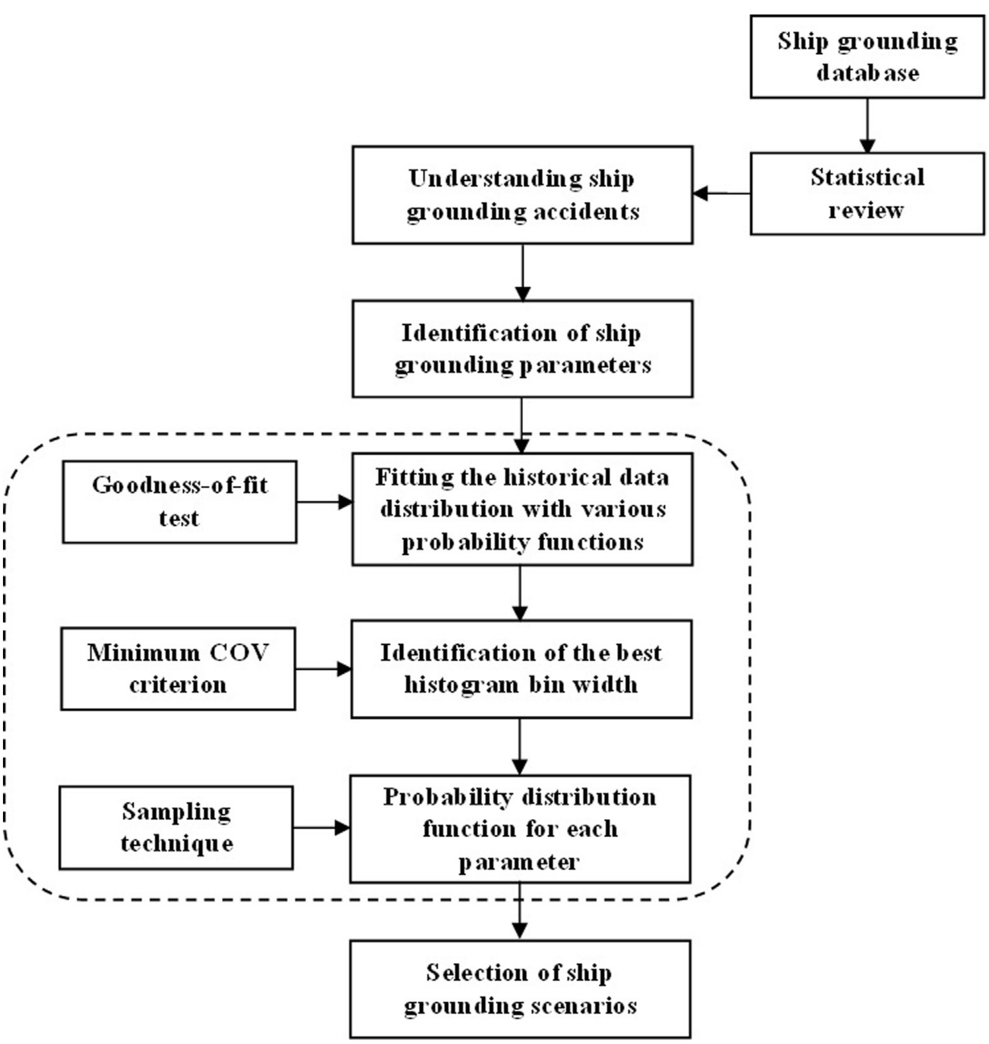

Fig. 2. Framework of selecting the grounding scenarios.