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A Quasi-dynamic Approach for the Evaluation of Structural Response in Ship Collisions and Groundings

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ABSTRACT

The analysis of dynamic response of ships in accident scenarios requires realistic idealization of the environmental actions for different ship operational conditions. This paper presents a procedure for fluid structure interaction (FSI) modelling of ships involved in typical collision and grounding events. The method implements LSDYNA / MCOL models that account for 6-DOF hydrodynamic actions (added mass, restoring forces, buoyancy, damping forces) and the influence of evasive speed in way of contact. Preliminary simulations for accident scenarios involving passenger ships confirm that the influence of FSI idealizations may be critical for either collision or grounding events primarily because of the influence of hydrodynamic restoring forces.

KEY WORDS:

Ship safety; dynamic response; grounding; collision; Fluid Structure Interactions (FSI); maneuvering

INTRODUCTION

Ships are exposed to various accidents (e.g. collisions, groundings, fires, explosions, etc.) during operations. According to EMSA (2018) from 2011 – 2017, 56.1% of the 14,002 ship casualties have been recorded as navigational accidents. Of those, 23.2% related to collision, 16.3% to contact, and 16.6% to grounding/stranding (see Fig.1).

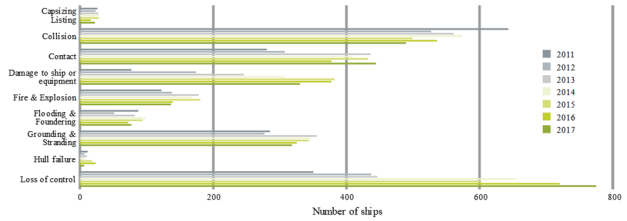

Fig. 1 Distribution of casualty events during 2011-2017 (EMSA, 2018).

Whereas it is broadly accepted that accidents involving oil tankers may cause environmental pollution (ITOPF, 2019), all accidents may impact upon human life. In an attempt to further demonstrate the latter Fig. 2 presents two representative collision and grounding events. On 16 Aug. 2013, the collision of a cargo ship with MV St. Thomas Aquinas caused 108 deaths and 29 missing. The grounding of Coast Concordia passenger vessel on 13 Jan. 2012 led to 32 deaths.

(a) MV St. Thomas Aquinas collision disaster (striking ship)

(b) Coast Concordia grounding disaster

Fig. 2. Representative (a) collision and (b) grounding accidents.

To prevent and/or minimize the damage by accidents, it is required to mitigate risks in design and operations. Currently, SOLAS (2017) includes regulations of relevance for passenger and cargo ships other than Bulk Carriers and Tankers introduced by the IACS (2019) Common Structural Rules (CRS). SOLAS regulations idealize the influence of collision and grounding events in the form of box-like damage extents (DNV·GL, 2015). Yet, it is still needed to evaluate the influence of realistic operational and environmental conditions on damage, because the conservative nature of the box-like damage impedes structural safety developments by not accounting potential reductions in damage size offered by novel crashworthy structures.

The literature presents various models and procedures on collision and grounding mechanics using both analytical and simplified methods that could be used toward this direction. For example, for the case of grounding, Nauyen et al. (2011) studied the effect of rock size and friction coefficients using a 2 cargo hold section. More recently, Prabowo et al. (2017) introduced the effect of rock-structure interaction by deformable rocks. Various other studies developed simplified methods by model tests or numerical simulations (Simonsen, 1997; Pedersen and Zhang, 2000a; 2000b; Glykas and Das, 2001; Zhang and Suzuki, 2006; Paik and Seo, 2007; Hong and Amdahl, 2008, Haris and Amdahl, 2012; Yu et al., 2013; Zeng et al., 2016). Liu et al. (2015) conducted both experimental and numerical investigations on bottom damage and developed a simplified analytical method considering grounding. To date the approach by Simonsen (1997) could perhaps be received as the most realistically representative in terms of the quality of simplifying assumptions. The effects of collision parameters on