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Statistical analysis of ship accidents and review of safety level

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ABSTRACT

Safety may be defined as an acceptable state of risk by society. In this respect, for assessing the current safety level of ships, it is necessary to quantify the risk level of the operating world fleet, thus estimate and assess the basic contributors to risk, namely the frequency of maritime accidents and the extent of their consequences. The present investigation was motivated by earlier published work of Det Norske Veritas (DNV, 2006), in which they were some alarming signals of worsening of the level of maritime safety. A justified question therefore is whether and how the level of ship safety changed thereafter. Recalling that a fundamental step of a Formal Safety Assessment of maritime assets is the investigation of relevant casualty reports and the analysis of historical data, which characterise the maritime safety performance in the studied period, the herein presented work deals with a systematic analysis of ship accidents in the last decade as a way to evaluate the current level of safety for the majority of ship sub-types present in the world merchant fleet and to conclude on the foreseeable future. The presented analysis also includes a deeper investigation about possible relationships between accident rates and ship's age, which proved more complex than initially thought. The outcome of the present study indicates that in the last decade although the frequencies of ship accidents generally increased, the *safety level* of various ship types did not significantly change, as the consequences of accidents remained in average at about the same level.

1. Introduction

The history of maritime transport is marked by ship accidents with partly disastrous consequences on human lives and impact on society and the marine environment. In response to these disastrous accidents, more and more new requirements and amendments of existing regulations for the safe maritime transport were introduced by the International Maritime Organisation (IMO). A remarkable example in this respect is the improvement of safety of tanker operations after year 1990, which is marked by the catastrophic marine pollution accident of the *Exxon Valdez*[1] tanker in Alaska in 1989; namely, the introduction of new regulations and guidelines, of safety codes and improved crew training schemes which all contributed to a drastic reduction of accident frequencies thereafter (Eliopoulou and Papanikolaou, 2007). They led to an improvement of the maritime safety culture, with the shipping industry adopting more and more a proactive approach to ship operation. Noting that an overwhelming part of marine accidents (more than abt. 80%) is attributable to human factors, it may be concluded that introduced measures addressing ship's operation (*active* safety measures) were very effective in the reduction of accident frequencies, whereas measures affecting ship's design and technology (*passive* safety measures) have more contributed to the mitigation of accident consequences (for which achieved reduction and control were not that significant). Fig. 1 presents a snapshot for the development of navigational (collision, grounding, contact) accident frequencies for AFRAMAX tankers from the late 70ties and up to the early 2000. In the graph, we have marked the implementation of some key regulations and safety codes that could be held responsible for the declining trends of particular rates.

Although Fig. 1 pertains at first only to AFRAMAX tankers, relevant trends may be qualitatively extended to all tanker categories and even to other ship types, as most of the noted specific regulations were applied to *all ship types*; exceptions apply to VETTING and the 94 SOLAS ISM, which are applicable only to oil carrying tankers. The essence of the above snapshot, however, capturing a

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[1] The *Exxon Valdez* was that largest oil spill in US waters until the *Deepwater Horizon* offshore spill in 2010; the estimated volume of the spill is being disputed and is ranging between 41,000 and 119,000 m^3, impacting 2100 km of the Alaskan shoreline; the associated oil spill costs exceeded 7 billion USD; acc. to the International Tanker Owners Pollution Federation (ITOPF), it was the 'most expensive oil spill in history', even though not the largest one by the amount of spilt oil of tankers (Eliopoulou et al., 2012).

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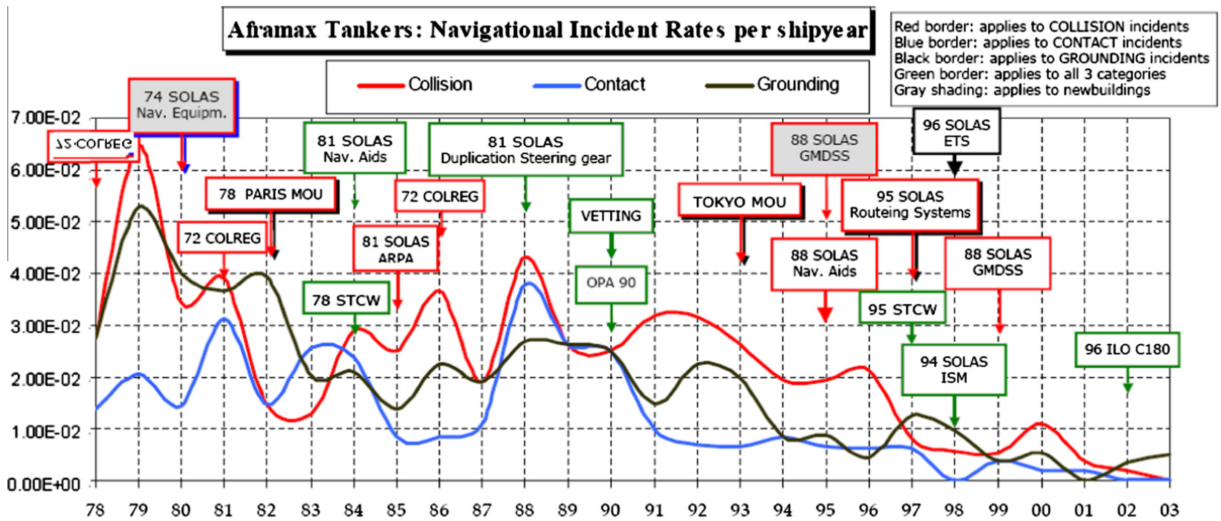

Fig. 1. Timeline of navigational accident rates vs. introduced international maritime regulations, safety guidelines and codes (Eliopoulou and Papanikolaou, 2007).

period of $2^{1/2}$ decades, is that the frequencies of navigational accidents were *reduced for the collisions and groundings by a factor of close to 10*, and to a lesser (but still significant) degree for the contacts. However, in the post 2000 period, frequencies of occurrence of serious accidents started increasing again, according to the present study, which is at first alarming and subject of the present paper.

Relatively late compared to other industries (land- and air transport, energy/nuclear industry) and not simply responding to maritime disasters, IMO introduced in year 2000, a formalised procedure for the assessment of ship safety, known from other safety critical industry systems, namely the Formal Safety Assessment process (FSA). FSA is a formalised risk assessment methodology aimed at enhancing maritime safety by using risk analysis and cost benefit assessment. FSA was originally developed (at least partly) as response to the *Piper Alpha* disaster of 1988, when the particular offshore platform exploded in the North Sea and 167 people lost their lives. Fig. 2 shows schematically the major steps of FSA. Step 1 includes the identification of all possible hazards of the problem under investigation leading to a list of relevant accident scenarios with potential causes and outcomes. In Step 2, a risk analysis is performed in order to evaluate all relevant risk factors. The step includes the determination of the frequency rates of identified major accident categories and of their consequences by statistical analysis of historical data. In Step 3, various risk control options (RCOs) are identified aiming at controlling the ensuing risk factors and mitigating the consequences of accidents. The viability of selected risk control options are examined by a cost benefit assessment (CBA) determining the cost effectiveness of each alternative risk control option (Step 4). In the final Step of FSA, recommendations for decision-making are given (Wang, 2001).

In 2002, IMO approved the guidelines on Formal Safety Assessment (MSC/Circ.1023, 2002) in order to support decision making in relation to the introduction of new regulations; they namely introduced a process formalising the assessment of new regulations using risk analysis and cost benefit assessment techniques (Skjong, 2002, 2009). The particular Guidelines were amended by MSC/Circ.1180-MEPC/Circ.474 in 2005 and further revised in 2013 (MSC-MEPC.2/Circ. 12, 2013). Based on this procedure, a series of high level FSA studies were elaborated within the EU funded research project SAFEDOR for the most important ship types, namely Containerships (MSC 83/INF.8, 2007), LNG ships (MSC 83/INF.3, 2007), Cruise ships (MSC 85/INF.2, 2008), RoPax ships (MSC 85/INF.3, 2008) and Large Crude Oil tankers (MEPC 58/INF.2, 2008). The accident statistics of the pre-mentioned FSA studies concerned mainly the time period 1990 (or 1993) to 2004, depending on the availability of data in the EU funded project SAFEDOR (2005–2009). For some ship types, it was considered necessary to update the historical analysis of casualty data and consequently the risk assessment of the particular FSA study. In this respect, an update of the FSA for fully cellular containerships was performed (Eliopoulou et al., 2013; Hamann et al., 2013). Focusing on the passenger ships, two sequential thorough re-investigations were done through the EU funded project GOALDS (Papanikolaou et al., 2013) and the EMSA III project (Pagiaziti et al., 2015). Further significant risk assessment case studies in the maritime field were recently presented by Montewka et al. (2014) and Goerlandt and Montewka (2015).

The herein presented investigation started as an update (Papanikolaou et al., 2014) of similar research work conducted a decade ago by DNV (DNV, 2006) and went deeper into relationships of accident frequencies and consequences to ship age (Voulgarellis, 2015). The objectives of the present paper are the quantification of the risk level of the operating world fleet by statistical analysis of historical data and the assessment of the safety level of all basic merchant ship types in terms of accidents' occurrence, initial frequencies and basic consequences. For each ship type, accidents occurred in the time period 2000–2012 are being analysed and presented with respect to accident category, total losses of ships and number of fatalities. Furthermore, the complex relationship between accident rates and ship age is also investigated and the various contributing factors discussed.

The paper is organised as following: After a general introduction to maritime safety, the interaction between marine accidents and international regulatory developments at IMO and the introduction of Formal Safety Assessment, we present a statistical analysis of historical casualty data, in which we elaborate on the statistical sampling plan and operational world fleet at risk; a review of the obtained major results of the analysis follows, in which we first comment on the yearly frequencies of the recorded serious accidents per accident and ship type for the period 2000–2012; in the same frame, a conducted more specific analysis considers a sampling plan of the ships categorised by their age and studies the impact of ship's age on the frequency of accidents, which is not uniform; a similar parametric analysis follows for the consequences of serious accidents in terms of total ship losses and fatalities of People On Board (POB); a timeline analysis regarding the sufficiency of the used statistical sample by use of Kendall's