Ocean Engineering 163 (2018) 502–517

Contents lists available at ScienceDirect

Ocean Engineering

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

Statistical analysis and critical review of navigational accidents in adverse weather conditions

N.P. Ventikos[b,*], A.D. Papanikolaou[a], K. Louzis[b], A. Koimtzoglou[b]

[a] Ship Design Laboratory, School of Naval Architecture and Marine Engineering, National Technical University of Athens, 9 Iroon Polytechneiou, 15773, Zografou, Greece
[b] Laboratory for Maritime Transport, School of Naval Architecture and Marine Engineering, National Technical University of Athens, 9 Iroon Polytechneiou, 15773, Zografou, Greece

ARTICLE INFO

Keywords:
Adverse weather conditions
Navigational accidents
Ship safety
IMO
Emissions control

ABSTRACT

The latest IMO regulatory requirements concerning the control of toxic gas emissions from ships have sparked interest in whether ships are adequately equipped to operate safely in adverse weather conditions when compliance is achieved simply by the reduction of power. This paper deals with the analysis of navigational accidents (collision, grounding, and contact accidents) that occurred in adverse weather conditions and may have been related to the lack of sufficient powering and manoeuvrability. The analysis aims to potentially assist the IMO regulatory work in setting rational margins of minimum powering of ships for safely operating in adverse weather conditions.

1. Introduction

The International Maritime Organization (IMO), leading the efforts to reduce toxic gas emissions from maritime operations, has introduced the Energy Efficiency Design Index (EEDI) requirement for new ships, in the IMO Resolution MEPC.203(62) (IMO, 2011). The EEDI is expressed in grams of emitted CO_2 by the distance the cargo has been transported (g CO_2/t nm) and is intended to be a driver for limiting the emissions of toxic gases from new ships. Concerns have been raised that relate to the speculation that compliance with the EEDI requirement might be accomplished simply by installing smaller main engines on new ships. However, this decision could have a negative impact on the safe operation of ships in adverse weather conditions by a subsequent reduction of the capability of ships to maintain their manoeuvrability, as highlighted by the International Association of Classification Societies (IACS, 2010). The negative impacts of having inadequate propulsion power in adverse weather conditions include the inability to maintain or change course especially in restricted navigational areas (Shigunov and Papanikolaou, 2014), and the inability to maintain ship speed.

The work carried out by IACS led to the introduction of the 2013 Interim Guidelines for determining minimum propulsion power by the IMO Resolution MEPC 232 (65) (IMO, 2013a), followed by amendments by the IMO Resolutions MEPC 255 (67) (IMO, 2014) and MEPC 262 (68) (IMO, 2015). The scope of the guidelines covers new ships that need to comply with the EEDI requirements in unrestricted navigation and which are equipped with a conventional propulsion system. The purpose of the 2013 Interim Guidelines is to ensure that ships dispose a minimum power that is adequate for maintaining manoeuvrability and navigational safely in adverse weather conditions. The criteria for determining the minimum propulsion power in adverse conditions depend on ship size/type and were derived on the basis of the EEDI reference lines. In addition, the guidelines define what is considered "adverse weather condition" as a function of ship size expressed by its length between perpendiculars (L_{PP}). The corresponding range of environmental parameters associated with adverse conditions is 4.0–5.5 m significant wave height (h_s), which corresponds to sea states 5–7 (rough to high) on the Douglas scale, and 15.7–19.0 m/s mean wind speed (V_w), which corresponds to level 8 (gale) on the Beaufort scale.

Because ships often operate in weather conditions that are worse than those embedded in the Interim Guidelines and should be taken into account in their design (Bitner-Gregerse et al., 2016), concerns were expressed by the maritime industry about the margins for wave height and wind speed values that determine what is considered "adverse weather" and what is considered adequate propulsion power to maintain manoeuvrability according to the IMO 2013 Interim Guidelines. These concerns were the basis for the project SHOPERA (Energy Efficient Safe Ship OPERAtion), which was funded by the European Commission under the FP7 framework (Papanikolaou et al., 2015). The objectives of this research project were, among others, to specify the environmental conditions for assessing sufficient propulsion power, as well as to assess the safety margins of ships that navigate in adverse weather conditions (Papanikolaou et al., 2016).

* Corresponding author.
E-mail address: niven@mail.ntua.gr (N.P. Ventikos).

https://doi.org/10.1016/j.oceaneng.2018.06.001
Received 2 November 2016; Received in revised form 1 June 2018; Accepted 4 June 2018
0029-8018/

This paper presents part of the work of project SHOPERA and builds on the research of Ventikos et al. (2015) by introducing specific met-ocean data (wave height and wind speed) into the analysis for accidents that occurred from 1990 up to 2013. This work involves the analysis of navigational accidents, recorded in the IHS/Sea-Web™ database (IHS, 2013), which happened in severe weather conditions and may be related to the failure of powering and manoeuvrability. The analysis of the severity of the weather during these accidents should enable a (not strictly) qualitative comparison with the definition of "adverse conditions" in the 2013 Interim Guidelines of the IMO. The ultimate goal is to potentially assist the IMO regulatory work in setting rational margins of minimum powering of ships for safely operating in severe/adverse weather conditions.

The next section describes the methodology of the conducted analysis. Thereafter, the results of the statistical analysis of the accident sample are elaborated; namely, it includes a general description of the accident sample, the distributions that are indicative of ship size, the analysis of the annual number of accidents, and the relative frequencies of the accidents of interest per ship-year. The section after presents the analysis of the prevailing weather conditions at the time and location of the accident. The paper concludes with a commentary of the most significant results and insights that relate to the limits for adverse weather conditions set by the IMO 2013 Interim Guidelines.

2. Methodology and data verification

The scope of the analysis includes navigational accidents (i.e., collision, contact, and grounding accidents) that have occurred in severe/adverse weather conditions in navigational/limited waters, which might be related to manoeuvrability issues due to the lack of adequate powering and/or steering. Compared to other accident types, such as founderings, this type was considered more likely to occur due to lack of sufficient power and/or steering. The reasoning for the selection of navigational/limited waters in the analysis is that ships operate there with lower speeds, compared to open water navigation, while their manoeuvring (efficiency of their steering devices) capability is greatly affected in severe/adverse weather conditions (i.e., strong winds and large waves). Thus, the safety problem at hand is not simply a 'minimum powering problem', but a manoeuvrability problem in limited waters and severe weather conditions (Shigunov-Papanikolaou, 2014).

The main research questions of this work are: which ship types and size classes are most vulnerable, how often the accidents of interest have occurred in the past, and whether the prevailing weather conditions during the accidents are comparable with those defined as "adverse conditions" in the Interim Guidelines. The methodology of the analysis comprised the following steps: 1) gather information on the accidents of interest, 2) screen the information to identify the cases that are more likely to have been caused by a lack of sufficient propulsive power, 3) identify the size classes for each ship type that seem most vulnerable to this hazard, 4) determine the frequency and possible temporal trends of the accidents of interest, and 5) determine the prevailing weather conditions.

A structured accident database was compiled from multiple data sources with specific inclusion criteria (see Table 1). The records for each accident in the database were organized into the following information groups: ship details, ship dimensions, machinery data, accident details, and weather information. Accident information was mainly obtained from the IHS/Sea-Web™ marine casualty database (IHS, 2013) and the public area of the marine casualties and incidents database of the IMO; the Global Integrated Shipping Information System-GISIS (IMO, 2013b). These sources are among the most reliable and frequently used accident databases in the maritime industry.

The IHS/Sea-Web™ marine casualty database classifies the prevailing weather conditions on a qualitative scale, which means that there may be no quantitative weather-related information such as significant wave height and wind speed at the time of the accident. Therefore, weather-related information was provided by partners participating in the project SHOPERA, namely DANAOS Shipping Company Ltd and the Instituto Superior Tecnico (IST) – Centre for Marine Technology and Engineering (CENTEC), as well as relevant published accident reports. The wave height information that was provided by partners in the project SHOPERA are significant wave height values for the approximate time and location of the accidents of interest and were originally derived from model hindcasts as well as from statistical analysis of buoy measurements. It should be noted that the obtained significant wave height values were used in this analysis as provided, without any further elaboration. From the available weather information for the accidents of interest, the maximum recorded significant wave height equals 7 m and the maximum recorded mean wind speed equals 21 m/s. These conditions correspond to a sea state 7 (high) on the Douglas scale and level 9 (severe gale) on the Beaufort scale (The Swedish Club, 2014).

After the initial data collection, the database contained N = 1666 navigational accidents that occurred in weather conditions, which included both heavy weather conditions and extreme weather events (12% of the accidents). Subsequently, a structured verification process with specific filtering criteria was conducted to ensure the validity of the original data and to ensure the relevance of the included cases to the scope of the analysis. As most maritime accident databases do not provide adequate information on the causes of the recorded incidents (Psarros et al., 2010), the possibility of a lack of propulsive power to actually be a root cause for the accidents of interest was indirectly determined with a set of specified criteria. Falsely including an irrelevant case would distort the conclusions of the analysis and provide misleading results, considering that effective risk mitigation depends on determining the true root causes of an accident (Antão and Guedes Soares, 2002).

As shown in Table 2 only 17% were considered relevant to the analysis (i.e., 1389 accidents were excluded). The highest retention rates are observed for Ro-Ro Ferries and Cruise Ships (29% and 27% of the initial sample per ship type, respectively), which indicates that these types of ships might be more frequently involved in accidents related to a potential lack of manoeuvrability in adverse weather conditions.

Stage I. This stage involved an initial screening based on the accident category and resulted in the exclusion of 753 cases. Indicative examples of cases that are considered out of the scope of the analysis are cases where propulsive machinery was not damaged in any way, or the hull of the ship was intact, and the ship was not laid up for repairs. As a result, the following accident categories were excluded from the analysis: hull and machinery damages, including failures on the main engine or the generators, blackouts, hull cracks and failure of bow thruster, propeller, rudder, and stabilizer; accidents that are caused by fire/explosion in machinery, cargo spaces or in the accommodation; any accident where the ship sank due to either ingress of water or cargo shift; accidents that occurred while the ship was in shipyard or dry dock.

Stage II. This stage resulted in the exclusion of 153 cases by applying the following filters: the Froude number (Fn) and the severity of the accident. Ships with a Froude number greater than 0.5, were considered High-Speed Crafts and were excluded, due to the fact that High-Speed Crafts are usually equipped with high powered main engines in order to achieve high service speeds (Antão and Guedes Soares, 2008). Therefore, High-Speed Crafts are unlikely to face manoeuvrability issues due to lack of main engine power. This filter was mainly applicable to Cruise ships and Ro-Ro Ferries, as they operate at greater service speeds compared to the other ship types under consideration.

A serious accident is one that results in one of the following (LRFP, 1995): Structural damage, rendering the ship unseaworthy, such as penetration of hull underwater, immobilization of main engines, extensive damage, etc.; Breakdown; Actual Total Loss; Any other