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Special Issue on the Recent Advances in Safe Maritime Operations under Extreme Conditions

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1. Introduction

The increased activity in the Arctic involves hazards such as a harsh environment, especially the ice cover and cold temperature, remoteness and lack of infrastructure, and lack of information about bathymetry, among others. Ice cover is also highly variable and dynamic, with increasing variation in the future as, due to the changing effects of the world climate, the ice conditions on all ice-covered areas are also under dynamic change. This effect on Arctic operations is a complicated problem to solve. The remoteness of the Arctic areas means that in case of an accident, the search and rescue (SAR) capability is low. Further, the fairways are not marked very extensively, and the soundings taken for charting are relatively scarce. These polar area hazards are compounded by the fact that the rate of recovery of nature is slow, meaning that environmental hazards are made more serious.

The focus of this Special Issue is research related to the recommended practices of scenario-based risk management for polar shipping and risk-based guidelines considering holistically the impact of risks on ice-infested waters. These include: (a) definition of ice conditions, (b) ship–ice contact, (c) numerical models/idealizations, (d) definition of limit states for ice-strengthened structures, and (e) holistic risk–reward analysis for polar navigation.

2. Summary of Contents

This special includes six original research articles on recent advances in safe maritime operations under extreme conditions.

Bergström and Kujala [1] present a discrete event simulation-based approach for assessing the operating performance of the Finnish–Swedish winter navigation system (FSWNS) under different operating scenarios. Different operating scenarios are specified in terms of ice conditions, the volume of maritime traffic, number of icebreakers (IBs), and regulations such as the energy efficiency design index (EEDI). Case studies indicate that, unless the number of IBs is increased, the EEDI regulations may result in a significant increase in both the number of instances of IB assistance and the cumulated IB waiting times.

Brown et al. [2] present a new framework that augments the current POLARIS methodology to model consequences. It has been developed on the premise that vessels of a given class with higher potential life-safety, environmental, or socio-economic consequences should be operated more conservatively. The framework supports voyage planning and real-time operational decision making through assignment of operational criteria based on the likelihood of ice-induced damage and the potential consequences. The objective of this framework is to enhance the safety of passengers and crews and the protection of the Arctic environment and its stakeholders.

Li et al. [3] present a three-dimensional numerical simulation model of an oil spill for application in emergency treatment methods under icy water conditions. The combined effects of wind, wave, current, and ice implemented in their model correspond to Arctic Ocean conditions. A discrete element method combined with an overset grid was adopted



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to track the trajectory movements of an oil film with medium-density ice floes and simulate the flow field of moving ice of large displacement in six degrees of freedom (6DOF). The probability of oil spill area extensions were estimated by a response surface method (RSM). The results show a reduced risk of pollution in icy water conditions and greater drift action of oil film. Accordingly, the spraying location and quantity of oil dispersant could be rapidly specified.

Zhang et al. [4] present a simplified numerical model to predict ice impact forces acting on a ship's hull in level ice conditions. The model is based on ice–hull collision mechanisms and the essential ice-breaking characteristics. The two critical ice failure modes, localized crushing and bending breaking, are addressed. An energy method is used to estimate the crushing force and the indentation displacement for different geometry schemes of ice–ship interaction. The ice bending breaking scenario is taken as a semi-infinite plate under a distributed load resting on an elastic foundation. An integrated complete ice–hull impact event is introduced with ice failure modes and breaking patterns. Impact location randomness and number of broken ice wedges are considered in order to establish a stochastic model. This model can be used to predict ice impact loads, and to establish a link between design parameters (ice properties and ship geometry) and structural loads.

Idrissova et al. [5] analyze the effect of the assumptions behind the Popov method by comparing ice load predictions, calculated by the method, with corresponding full-scale ice load measurements. The findings indicate that assumptions concerning the modelling of the ship–ice collision scenario, the ship–ice contact geometry, and the ice conditions, among others, significantly affect how well the ice load prediction agrees with the measurements.

Leira et al. [6] illustrate the most likely combinations of the statistical properties of the parameters that characterize ice ridges and icebergs, using the so-called environmental contour method. Probabilistic models of the key parameters that govern the ship–ice interaction process are introduced. Subsequently, the procedure referred to as the inverse reliability method (IFORM) is applied for identification of the environmental contour. Different forms (i.e., dimensions) of environmental contours are generated to reflect the characteristics of the interaction process. Furthermore, the effect of an increasing correlation between the basic parameters is studied. In addition, the increase in the design parameter values for increasing encounter frequencies is illustrated.

3. Perspectives on Future Research

Climate change is expected to cause rapid changes in sea ice conditions, increasing the volume of shipping in icy waters. The current experience-based determination of ice-induced loads on ships, primarily derived from historical data, are not suitable for handling the related challenges. Therefore, new approaches are urgently needed, based on detailed full-scale measurements, as well as an in-depth understanding of the physics of the ship–ice interaction. The main challenges are related to modelling the icebreaking process, due to its stochastic nature, and due to large variations in the prevailing ice conditions and material properties. Despite significant research efforts, no clear link between ice-induced loads and the prevailing ice conditions exists. The resulting uncertainty in ship design translates into significant risks to people and the environment.

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