

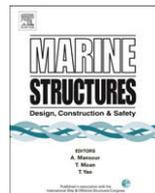


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A step towards risk-based decision support for ships – Evaluation of limit states using parallel system analysis

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ABSTRACT

Onboard decision support systems (DSS) are used to increase the operational safety of ships. Ideally, DSS can estimate future ship responses within a time scale of the order of 1–3 h taking into account speed and course changes, assuming stationary sea states. In principle, the calculations depend on a large amount of operational and environmental parameters, which will be known only in the statistical sense. The present paper suggests a procedure to incorporate random variables and associated uncertainties in the calculations of the outcrossing rates that are the basis for risk-based DSS. The procedure is based on parallel system analysis, and the paper derives and describes the main ideas. The concept is illustrated by an example, where the limit state of a non-linear ship response is considered. The results from the parallel system analysis are in agreement with corresponding Monte Carlo simulations. However, the computational speed of the parallel system analysis proved slower than expected.

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1. Introduction

In the future, various kinds of onboard guidance and monitoring systems will likely become standard practice in ships to assist the ship master navigate under non-normal conditions; in particular during storm and rough sea. In principle, this means that an objective system – the decision support systems (DSS) – supports the ship master in making suitable decisions with respect to speed and course changes, so that specific ship responses are kept at an acceptable level.

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There exist a variety of decision support systems of which many are already in operational use. A comprehensive overview of state-of-the-art systems has been carried out within the EU project ADOPT (Advanced Decision Support System for Ship Design, Operation and Training), e.g. Tel-lkamp et al. [21], under the Sixth Framework Programme governed by the European Community. Some of the systems that are considered include, among others, the OCTOPUS Onboard [18] by Amaron, the Seaware EnRoute Live [19] by Seaware Onboard, the Vessel Optimization and Safety System [22] by Ocean Systems, and the SeaSense system [15] by FORCE technology. The authors have themselves been involved in part of the development of the SeaSense system. This system fuses the information of several onboard sensors which measure responses such as vertical wave induced bending moment amidship, accelerations at AP and FP, relative wave height, and green water occurrences on deck. The SeaSense system makes estimations of the sea state by use of a simplified version of the wave buoy-analogy, where measured ship responses are used to estimate the directional wave spectrum, e.g. Nielsen [16] and Iseki and Terada [6].

In general, decision support systems combine information on the on-site sea state with various kinds of pre-calculated or online response calculations to obtain statistical information about future responses to be expected. Implicitly, the statistical predictions depend on all operational parameters such as speed, metacentric height, relative wave heading, mass distribution, etc. In addition, the predictions will be directly influenced by parameters describing the sea state; e.g. significant wave height and zero-upcrossing period. Under real operational conditions the problem is that none of these parameters are known exactly, which means that the parameters must be described in terms of random variables with related uncertainties. If guidance systems are to give the most valuable and/or reliable support, it is therefore essential that all the uncertainties in the random variables are taken into account. This area has therefore been given special attention by the ADOPT project and, thus, one of the work packages (WP3) specifically focused on strategies for limit state evaluation including uncertainty analysis and the present paper outlines some of the findings of WP3 with special consideration to parallel system analysis for obtaining the mean outcrossing rate. Some general ideas and concepts of risk-based decision support systems are given by Bitner-Gregersen and Skjong [1], and Spanos et al. [20] consider the concept of a DSS to handle, specifically, Gaussian, narrow-banded processes.

It should be emphasised that the focus of the paper, as it will appear, basically concerns the calculation of the expected value of the mean outcrossing rate of a given process. Although the presented methodology here has its overall relevance to decision support systems for ships, as cited in the title of the paper, these systems and their principles and applications will not be dealt with in any further details. This means that the central role of a DSS – the interaction of predictions with measurements from sensors – is not touched upon in the paper.

2. Definitions and objective

Fig. 1 illustrates the behaviour in time t of a general response $Z(t, \mathbf{X})$ that depends, in some way, on the parameters of the vector \mathbf{X} . It is assumed that the response depends non-linearly on the wave excitation. In the figure, a threshold value, say ζ , has been indicated by a dashed horizontal line. Thus, the number of crossings relative to the threshold value can be counted, which means that the outcrossing rate for the

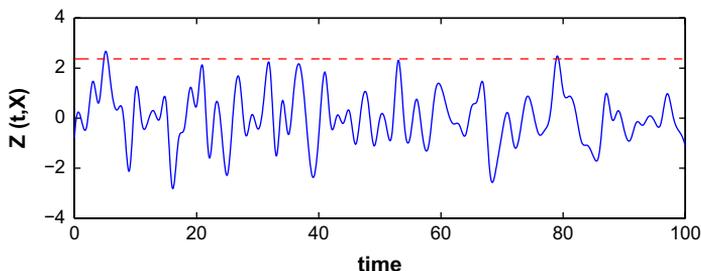


Fig. 1. Time variation of general (non-linear) process.

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