RELIABILITY ANALYSIS IN SHIP DESIGN

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Abstract

This paper presents a review of applications of reliability analysis methods to ship design problems. Considering operational systems in the first place, load-bearing structural subsystems will then be touched on briefly. In more detail, the simplifying idealization of the whole ship as one structural element will be dealt with, because this approach has given practical results that can be used in a load and resistance factor design method. Since the problems of statistical model uncertainties and stochastic finite element applications to ship structures have drawn some attention in ship design they are considered accordingly. Eventually, the problem of fatigue reliability and the related inspection planning problem are being dealt with in some detail.

Introduction

Application of reliability analysis in naval architecture offers two main problems, which arise with the fulfillment of the following demands:

1. Mechanical modeling of ship structures has to be realistic and simple enough to be manageable in reliability analysis.

2. Statistical modeling of uncertainties (definition of distribution functions) of basic physical parameters for reliability analysis has to be realistic.

In the following, recent developments of reliability analysis and its application to ship structures will be reviewed with special consideration of these problems. It will, however, not always be possible to differentiate clearly between activities in naval architecture and offshore technology, since most researchers and designers engaged in the development of reliability analysis methods and their application to ship structures are also dealing with offshore structures and vice versa. Nevertheless, our main concern will be ships.
Systems

Statistical reliability as used since long in reliability analyses of operating systems, has recently found new interest in view of well defined importance measures, which can be used in structural reliability analysis of load carrying systems as well 1). Naval architects have successfully applied importance measures, e.g. to operating problems of tankers and of steering gears more than a decade ago 2) 3), and an introductory example taken from 3) might be in place here, Fig. 1.

Fig. 1: Simplified steering gear of a tanker

In the logical structure (fault tree) of the steering gear, which consists of about 40 elements, fault tree analysis defined about 200 failure mechanisms (min cuts) of order 1 to 4. Different importance measures were calculated on this basis for the elements and min cuts. In the discussion of the results it could be concluded that ranking of elements or failure mechanisms according to different importance measures provides a valuable basis for rational design decisions related to safety. The examples have shown that importance ranking is not very sensitive to data uncertainties (failure rates, repair times) if the data are realistically related to each other.

Presently, we realize that such analyses have influence on maritime safety decisions taken within the framework of developments of shipbuilding standards, rules or codes by international bodies, e.g. the International Association of Classification Societies (IACS) or the Intergovernmental Maritime Association (IMO). An example are new IMO regulations for tanker shipping, being under development.

Considering load carrying ship structures, application of branch and bound techniques, which were originally developed for truss and beam structures, also to ship structures cannot be very realistic because of necessary oversimplifications of the mechanical model of the ship structure. Nevertheless, one early investigation of the kind, published in 4), should be mentioned for completeness.