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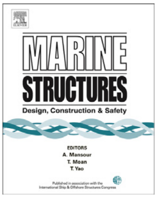

Local structural response to seakeeping and slamming loads

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ABSTRACT

A common approach to investigate the response of a structural detail such as a hatch corner is to compute the seakeeping loads using a linear 3D Boundary Element Method (BEM) and transfer the seakeeping loads to a Finite Element (FE) model of the ship structure. This approach is suitable for computations of the fatigue loading of structural details near amidships because a majority of the fatigue loading will occur in mild sea-states where the loading may be assumed linear. However, the linear seakeeping model may not hold when one investigates the ultimate response of the local bow structure of a ship which is designed to remain operational in severe conditions, for example, a frigate. A linear seakeeping analysis will significantly underpredict the loading at the bow because both the impulsive slamming loads and the non-linearities in the non-impulsive wave loads will contribute significant to the structural loading.

The non-linear loads require one to first derive a short-term distribution of the local structural response before the ultimate value of the response can be derived. A method to compute the short-term distribution of a structural detail is presented in this paper. The first step is to perform seakeeping analyses which includes slamming, non-linear Froude-Kryloff and hydrostatic loads. The short-distribution of the total hydrodynamic loading at the structural detail is obtained by simulating the seakeeping response for several hours. The response of the local structure is computed for the most severe impacts found in the seakeeping simulation. The hydrodynamic loading, including the non-linear contributions,

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is transfer to the structural model and the structural response is computed using the FE-method. The results of the structural analyses allow one to transform the short-term distribution of the structural loading to a short-term distribution of the response of the structural detail. A designer can obtain the ultimate structural response by entering the probability at which one accepts overloading of the structure in the short-term distribution of the response of the structural detail.

1. Introduction

Naval vessels, like frigates and destroyers, are relatively small ships, which are designed to operate in design conditions of sea-states 6 and higher. Operational demands require these ships to maintain high speed in these sea conditions which results in severe slamming loads. Although they are designed for such loads, an explicit demand for slamming loads is not in place or takes the form of a safety factor on the design wave bending moment. Local slamming loads are often described in terms of quasi static design pressures.

One would like to be able to compute the loading and response of the structure in the design phase to ensure that the structure can withstand the extreme seakeeping loads. A common approach for computing structural response is to compute the seakeeping pressures using a linear 3D-Boundary Element Method (BEM) and apply these pressures to a Finite Element (FE) model. That approach may not be valid when one would like to predict the response of the local structure in the forward part of the ship as slamming loads and other non-linear load components contribute significantly to the total loading of the local structure.

The non-linear loading also increases the complexity when identifying the extreme values of the structural loading and structural response. The ship structure is designed such that the probability of structural damage is very low in the anticipated operational conditions. To obtain design values, one needs to compute extreme values which have a probability equal to the probability at which one allows acceptable structural damage. The Rayleigh probability distribution can only be used as long as the loading is linear. Having obtained a known probability distribution it is straightforward to obtain the extreme values. In the case of non-linear loads, one needs to derive an accurate short-term distribution of the structural response to be able to compute the extreme values at the probability level where one accepts overloading of the structure.

The main aim of this paper is to investigate if it would be possible the derive the short-term distribution of the local structural response when accounting for non-linearities in the seakeeping loads. First a method to compute both the seakeeping response including slamming, non-linear Froude-Kryloff and non-linear hydrostatic loads is presented in this paper. The diffraction and radiation loads are kept linear to reduce the computational effort. The method includes the global hydro-elastic coupling, and the hydrodynamics of the rigid-body and elastic modes are also coupled. The method for computing the seakeeping response is extended to compute the hydrodynamic loading at the structural model which, in turn, is used to compute the structural response using the FE-method. A case study using a frigate is presented in the second part of this paper to illustrate how the short-term distribution of the local structural response can be obtained by combining seakeeping and structural analyses.

Ideally, one would also like to validate the result of the presented method. In this case, the computed short-term distribution of local structural response in a severe sea-state should be validated. Unfortunately, in this paper the authors do not have access to data which one allows to validate the short-term distribution of local structural response. First of all, only full-scale trial data can be used as local structural responses cannot be measured accurately during model experiments. Secondly, the response of the local bow structure should be measured during the full-scale trial. The exact sea-state during the trial should also be known and the duration of the sea trial should be long enough to derive