Marine Structures 22 (2009) 576–593

Contents lists available at ScienceDirect

Marine Structures

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

Numerical and experimental investigations into the application of response conditioned waves for long-term nonlinear analyses

Ingo Drummen [a,*], MingKang Wu [a,c], Torgeir Moan [a,b]

[a] Centre for Ships and Ocean Structures, Norwegian University of Science and Technology, Otto Nielsens Vei 10, NO-7491 Trondheim, Norway
[b] Department of Marine Technology, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway
[c] Norwegian Marine Technology Research Institute, P.O. Box 4125 Valentinlyst, NO-7450 Trondheim, Norway

A R T I C L E I N F O

Article history:
Received 15 March 2008
Received in revised form 14 November 2008
Accepted 7 December 2008

Keywords:
Response conditioned waves
Vertical bending moment
Nonlinear
Hydroelastic
Experimental
Strip theory
Containership

A B S T R A C T

The coefficient of contribution method, in which the extreme response is determined by considering only the few most important sea states, is an efficient way to do nonlinear long-term load analyses. To furthermore efficiently find the nonlinear short-term probability distributions of the vessel responses in these sea states, response conditioned wave methods can be used. Several researchers have studied the accuracy of response conditioned wave methods for this purpose. However, further investigations are necessary before these can become established tools. In this paper we investigate the accuracy by comparing the short-term probability distributions obtained from random irregular waves with those from response conditioned waves. We furthermore show how response conditioned wave methods can be fitted into a long-term response analysis. The numerical and experimental investigations were performed using a container vessel with a length between perpendiculars of 281 m. Numerical simulations were done with a nonlinear hydroelastic time domain code. Experiments were carried out with a flexible model of the vessel in the towing tank at the Marine Technology Centre in Trondheim. The focus was on the probability distributions of the midship vertical hogging bending moments in the sea states contributing most to the hogging moments with a mean return period of 20 years and 10 000 years. We found that the response conditioned wave methods can

* Corresponding author. Present address: Maritime Research Institute Netherlands, P.O. Box 28, 6700 AA Wageningen, The Netherlands. Tel.: +31 317 49 34 35; fax: +31 317 49 32 45.
E-mail address: i.drummen@marin.nl (I. Drummen).

0951-8339/$ – see front matter
doi:10.1016/j.marstruc.2008.12.002

very efficiently be used to accurately determine the nonlinear short-term probability distributions for rigid hulls, but either accuracy or efficiency is to a large effect lost for flexible hulls, when slamming induced whipping responses are accounted for.

1. Introduction

According to Airy wave theory, the most unfavourable wave condition for a vessel is not the wave of which all components have a peak at the same time instant, but the wave leading to a response for which this is the case. Using the ideas from Friis-Hansen and Nielsen [1], Taylor et al. [2] and Adegeest et al. [3], Dietz [4] formulated the most likely response wave (MLRW). Using the amplitude and phase angle information from the transfer function, this method uses linear theory to condition the incident wave profile to cause a predefined specific response at a certain time instant. At this time all of the responses' frequency components have a peak. The most likely response wave is a special case of the conditional random response wave (CRRW), which was reformulated by Dietz [4], based on the original idea of Taylor et al. [2]. The CRRW profile includes a random background wave within the MLRW profile, and is therefore more capable of correctly capturing the contribution of transient effects like those of whipping.

Using the conditioned wave sequence as input, time domain simulations or model tests can be carried out. Pastoor [5] showed that response conditioned wave methods can be used for predicting nonlinear short-term probability distributions of the midship vertical bending moments in an efficient manner. By combining these methods with the coefficient of contribution method described for instance by Baarholm and Moan [6] a very efficient way is found to predict the long-term extreme response. The coefficient of contribution method identifies the most important sea states contributing to the extreme response, and Baarholm and Moan [6] demonstrated that a nonlinear long-term load analysis for marine structures can be performed by considering only these few most important sea states. The accuracy with which the short-term probability distributions in these sea states can be predicted by response conditioned wave methods is then of interest.

Assuming a rigid hull girder, Dietz [4] compared nonlinear short-term probability distributions of the midship bending moments obtained using both the MLRW and the CRRW methods with results from brute force simulations, and found good agreement. He furthermore showed that the effect of the random background wave was of increasing importance for increasing vessel speed. For a flexible hull girder, bending moments obtained by the CRRW method also corresponded well with brute force results. The same can be said for the sagging moments by application of the MLRW method. The hogging moments, on the other hand, compared less well with results from brute force simulations. Dietz [4] stressed that he used only one time domain code and recommended further analysis with other types of vessels and comparison with results from model tests. Also, ISSC [7] recommended that response conditioning methods have to be verified with further numerical simulations and experimental results before they can become established tools.

The fundamental assumption of wave conditioning techniques is that the nonlinear response is a correction of the linear response. It is therefore important to investigate their applicability under severe conditions, when nonlinear effects are significant. The purpose of this paper is to compare the short-term probability distributions obtained from random irregular waves with those from response conditioned waves. Both the MLRW and the CRRW methods were investigated. We furthermore show how these methods can be fitted into a long-term response analysis. The numerical and experimental studies were performed using a container vessel with a length between perpendiculars of 281 m. The nonlinear hydroelastic hybrid time domain computer code developed by Wu and Moan [8] was used for the calculations. The focus was on the probability distributions of the midship vertical hogging bending moments in the sea states contributing most to the hogging moments with a mean return period of 20 years and 10 000 years. The experimental results were obtained by testing a four segment flexible model of the vessel in the towing tank at the Marine Technology Centre in Trondheim. In the