

Prediction of the Damping-Controlled Response of Offshore Structures to Random Wave Excitation

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Abstract

A method is presented for predicting the damping-controlled response of a structure at a known natural frequency to random wave forces. The principal advantage of the proposed method over those in current use is that the explicit calculation of wave forces is not required in the analysis. This is accomplished by application of the principle of reciprocity: that the linear wave force spectrum for a particular vibration mode is proportional to the radiation (wave-making) damping of that mode. Several example calculations are presented including the prediction of the heave response of a tension-leg platform. The directional distribution of the wave spectrum is included in the analysis.

Introduction

This paper introduces a simple procedure for estimating the dynamic response of a structure at each of its natural frequencies to the random excitation of ocean waves. The principal advantage of the proposed method is that the explicit calculation of wave forces has been eliminated from the analysis. This is made possible by a direct application of the reciprocity relations for ocean waves, originally established by Haskind¹ and described by Newman,² in a form that is easy to implement. Briefly stated, for many structures it is possible to derive a simple expression for the wave force spectrum in terms of the radiation damping and the prescribed wave amplitude spectrum. In general, such a substitution is of little use because the radiation damping coefficient may be equally difficult to find. However, the substitution leads to a very useful result when the dynamically amplified response at a natural frequency is of concern. In such cases it is shown

that, contrary to popular belief, the response is not inversely proportional to the total damping but is, in fact, proportional to the ratio of the radiation damping to the total damping. This is because the radiation damping and the wave exciting forces are not independent quantities. Therefore, in the absence of a reliable estimate of either the total damping or the ratio of the radiation component to the total, an upper bound estimate of the response still may be achieved because the ratio is, at most, one. The demonstration of the existence of this upper bound is one of the key contributions of this paper.

Linear wave theory is assumed; therefore, excitation caused by drag forces is not considered. However, for many structures drag excitation is negligible except for very large wave events. In the design process extreme events are modeled deterministically by means of a prescribed design wave and not stochastically as is done here. In many circumstances linear wave forces will dominate, and the results shown here will be applicable. Although drag-exciting forces are not included, damping resulting from hydrodynamic drag is included. Wave diffraction effects are extremely difficult to calculate. This analysis includes diffraction effects but never requires explicit evaluation of them.

It has been recognized that directional spreading of the wave spectrum is an important consideration in the estimation of dynamic response. In this paper such effects are accounted for in closed-form expressions. The evaluation of the expressions requires knowledge of estimates of the variation of the modal exciting force with wave incidence angle. However, only the relative variation of the modal exciting force as a percent of that at an arbitrarily chosen reference angle is required. Evaluation of the wave force in absolute terms still is not required.