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PREDICTION OF THE DAMPING CONTROLLED RESPONSE OF
OFFSHORE STRUCTURES TO RANDOM 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 results are applicable to a wide variety of fixed or floating structures. Potential applications include the response prediction of the fundamental flexural mode of a steel jacket structure, or the prediction of the heave, pitch, and roll responses of a tension leg platform. 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 widely overlooked principle of reciprocity; that the linear wave force spectrum for the particular vibration mode is proportional to the radiation (wave making) damping of that mode. Contrary to popular belief, the conclusions show that the response to wave excitation at a natural frequency does not grow without bound as the damping is decreased, but, in fact, reaches an upper bound, which is independent of damping. Several example calculations, including the prediction of the heave response of a tension leg platform are presented. The directional distribution of the wave spectrum is included in the analysis. The examples are structured so as to be easily extended to other applications.

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 over those presently used 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, which were established originally by Haskind¹ and described by Newman² 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.

The dynamic amplification of structural responses to random wave forces at a natural frequency is known to be strongly dependent on damping. This analysis shows that, for structures excited by random ocean waves, the response contributed by the damping controlled resonant band that includes the natural frequency is not governed by the total damping for that vibration mode, but, in fact, by the ratio of the radiation to the total damping.

As a consequence, knowing only the structural natural frequency of interest, the prescribed wave amplitude spectrum, and the ratio of the radiation to total damping for that vibration mode, it is relatively simple to estimate the mean square response of the structure in the frequency band that includes the natural frequency. If the ratio of the radiation to total damping is not known, an upper bound estimate of the mean square response still may be obtained.

Linear wave theory is assumed, and therefore, excitation due to 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.

There are numerous applications of present interest. For example, the fatigue analysis of a tension leg platform must include an estimate of the amplified responses at the natural frequencies of the structure in heave and pitch. This method quickly provides that response estimate. An example calculation for the heave response of a TLP is included. Two additional examples are provided, which exploit simplifications that frequently may be useful. The

References and illustrations at end of paper.