

A Perturbation Method of Direct Spectral Analysis for the Random Response of Offshore Structures

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ABSTRACT

A somewhat new method for solving the random response of the offshore platform, in which the parameters of structure or environment can be modified, is suggested in this paper. The perturbation method, combined with the direct spectral analysis method, has been developed to calculate the dynamic responses of the modified structure. The approach was successfully used for the random wave response of an offshore platform located in the Bohai Bay of China. Comparing with the result obtained by a traditional repeated analysis, its accuracy satisfies the engineering requirements, yet the computer time can be greatly saved. This newly developed method also is powerful for the dynamic analysis of random response of the offshore structure subjected to earthquake or ice forces.

INTRODUCTION

When the random wave response analysis for an offshore structure is performed, it is noted that the exciting forces are caused by the random process of the same source, although they act on most of the structure. Thus, it is reasonable to consider the random excitation force vector as a definite load distribution vector multiplied by a single random scalar quantity. According to the consideration, a direct spectral analysis method for random wave response has been developed (Zheng, 1985). In general, the calculation of input power spectral density function matrix begins with the wave spectrum via the fluid particle velocity and acceleration spectra, and finally obtains the input load spectrum (Borgman, 1967). The direct spectral method avoids this complicated calculation process, but the root mean square (rms) of both displacement and reaction force or the stresses in elements can be calculated easily.

Of the total calculation time for random wave response analysis of a system with higher number of degrees of freedom (DOF), a large portion is spent on the calculation for natural frequencies and modes. When the structure or environment is modified, in order to obtain corresponding response of the new system, a possible method is to repeat the eigen problem analysis and random response analysis. Obviously, it wastes a large amount of computer time. The subject of how to obtain the eigenvalues and eigenvectors of modified system rapidly has been discussed by many researchers, such as Chen (1977), Wang (1981) and Hu (1987). The matrix-perturbation method and reduced eigenvector method in dynamic reanalysis of piled offshore platform also were introduced (Zheng, 1990) and were successful in the calculation of natural frequencies and modes for a modified platform. Based on this and combined with the direct spectral analysis method, a new approach for the calculation of random response of a modified system has been developed in this paper. It is a perturbation method of direct spectral analysis.

As a test example, a simulated platform is modified in external diameter of the legs or in lumped mass of the deck. The changed natural frequencies, modes and random wave responses are calculated by a repeated calculation and a perturbation method. The example showed that the results obtained by the perturbation method were in agreement with those by a repeated calculation. The example included the condition of sea-organism growth on the platform surface. We also discussed the contribution of three components forming total modification of the random response. The approach in the paper has also been used in the real platform structures located in the Bohai Bay of China. One of them has 3,900 DOF. The reanalysis of the lowest 10 natural frequencies and modes only took 94 s of computer time. Whereas, using the repeated calculation, the work required 5,375 s. It is shown that the larger the number of system's DOF, the more remarkable the advantage to saving computer time.

A REVIEW OF DIRECT SPECTRAL ANALYSIS FOR RANDOM WAVE RESPONSE

When an offshore structure is subjected to a random excitation of wave, its equation of motion in a discrete form of finite elements method with mass matrix m , damping matrix c , stiffness matrix k and force vector f is written as:

$$m\ddot{x} + c\dot{x} + kx = f(t) \quad (1)$$

If the excitation is a stationary random process, the relationship between the output and input power spectral density function matrices $s_{xx}(\omega)$ and $s_{ff}(\omega)$ may be expressed as:

$$s_{xx}(\omega) = H_x(\omega) S_{ff}(\omega) H_x^{*T}(\omega) \quad (2)$$

in which the frequency response function matrix is expressed as:

$$H_x(\omega) = [-\omega^2 m + i\omega c + k]^{-1}$$

The asterisk denotes a conjugation.

Consider the exciting force $f(t)$ in Eq. 1. Zheng (1985) pointed out that it originated from the random process of a same source

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