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Wavelet Analysis of the Transient Response of Spar Platforms

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INTRODUCTION

In recent years, significant effort has been directed toward the numerical prediction of steady state response of the spar platform. Experimental measurements of the response are often used as a baseline for comparison to these numerical predictions, but it is usually impractical to achieve steady state conditions in the experiments. Therefore, for the purpose of making meaningful comparisons between numerical predictions of steady state response and experimental measurements, it is important to be able to determine quantitatively to what extent steady state conditions are met in the experimental data.

Difficulties in analyzing spar response transients arise from the presence of multiple frequencies that constitute the response. Before quantitative analysis of transient evolution of individual modes can be performed, it is necessary to first extract the modes from the response. For modes with amplitudes that vary as a function of time, Fourier analysis is not an effective technique because it decomposes a time series into Fourier modes with *constant* amplitude over all time. The wavelet transform, on the other hand, resolves frequency information as a function of time. Recently, for example, transient diagnostics based on the wavelet transform have been used by Staseweski (1997) and Ruzzene et al. (1997) to obtain natural frequencies and the decay rate of the individual modes in multiple degree-of-freedom response systems. In this work, the continuous wavelet transform is used as a tool to extract the modal envelopes of measured surge response directly in units of peak-to-trough amplitude.

CONTINUOUS WAVELET TRANSFORM

The continuous wavelet transform is defined as:

$$W(a,\tau) = a^{-1/2}\int_{-\infty}^{\infty} f(t)\psi^*\left(\frac{t-\tau}{a}\right)dt \tag{1}$$

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which is a projection of the signal $f(t)$ onto all scaled (denoted by a) and translated (denoted by τ) versions of the function, $\psi(t)$, and $W(a,\tau)$ are the wavelet coefficients. In this work the wavelet function, $\psi(t)$, is the complex-valued Morlet wavelet. The continuous wavelet transform is computed digitally using the implementation described by Jordan et al. (1997).

The wavelet transform of a signal can be viewed as analysis of the signal with a bank of band-pass filters. The scale, a, is related to the peak frequency of a given band-pass filter by:

$$f_p = \frac{0.7832}{a}, \tag{2}$$

determined by the expression given in Jordan et al. (1997). The modal envelope (peak-to-trough) of a response frequency is given as:

$$A(\tau) = \frac{2.0}{3.775}\sqrt{\frac{|W(a,\tau)|^2}{a}}. \tag{3}$$

The value of the scale, a, used to obtain $A(\tau)$ for a *particular* response frequency is computed from Eq. 2 and substituted into Eq. 3. The expression in Eq. 3 is equivalent to the generalized expression for a complex-valued wavelet given by Mallat (1998). The constant, 3.775, is specific to the Morlet wavelet and is equal to half of the peak magnitude of its Fourier transform.

RESULTS

In the experimental measurements examined here, the wave had a period of 21 s and a nominal wave height of 20 ft. The pitch natural response period of the spar was 66.8 s and the surge natural response period was 332 s. The surge response was measured with an optical tracking target located at the deck level of the spar, which was 179.9 ft (prototype units) above the mean water level (MWL). The experiments were directed by Deep Oil Technology and a detailed account of the experimental program can be found in the project report (1995).

The measured input wave elevation and the corresponding surge response for the spar platform are presented in Figs. 1 and