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Experimental Investigation of Wave Drift Damping and Slow Drift Motion in Bi-Frequency Domain

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INTRODUCTION

The response of large moored vessels and floating offshore structures to irregular seas is often dominated by large-amplitude, low-frequency quadratic nonlinear motions. As the use of such soft-moored systems for deep-water drilling, production and storage facilities is rapidly increasing, the development of more accurate numerical prediction tools, of which experimental verification is an integral part, becomes ever important.

Dalzell (1976) conducted the first model tests to determine the quadratic frequency response function (QFRF) for added wave resistance in random seas. QFRF for added resistance was theoretically analyzed by Dalzell and Kim (1976) and applied to the prediction of surge drift motion of a moored ship in random head seas by Kim and Breslin (1976). Slow drift motion of a moored vessel in random waves has usually been predicted in the time domain by solving an equation of drift motion using random drift force and damping coefficients estimated from experimental studies employing mono-chromatic waves—for instance, by Wichers (1987).

The objective of the present research is to develop an improved technique for prediction of slow drift motion due to random sea excitation by utilizing complete drift force and motion QFRFs and bi-frequency domain wave drift damping coefficients, as dictated by Volterra input-output theory. Given that second-order response in random seas is sensitive to the nonlinear interaction of many combinations of wave frequencies, it was considered important first to conduct a deterministic experimental investigation of the QFRF for slow drift motion of an idealized vessel/mooring system in a series of bi-chromatic waves. Further details of the experimental and theoretical investigation are given by Krafft and Kim (1990).

VOLTERRA MODEL

The quadratic Volterra polynomial is a model by which the slow drift force or motion of a large floating body subject to stationary Gaussian seas can be analyzed.

Utilizing the assumed symmetries of the QFRF in the bi-frequency plane, one needs only to consider the octants on either side of the positive ω_1-axis as shown in Fig. 1. In these octants, ω_1 is positive and $\omega_1 > |\omega_2|$. Wave frequency coordinates (ω_1, ω_2) are mapped into difference and sum frequency coordinates (Ω_1, Ω_2) as follows:

$$\Omega_1 = \omega_1 - \omega_2, \qquad \Omega_2 = \omega_1 + \omega_2 \tag{1}$$

Given simple bi-chromatic (dual) wave excitation defined by:

$$\eta(t) = a_1 \cos(\omega_1 t) + a_2 \cos(\omega_2 t), \qquad \omega_1, \omega_2 > 0 \tag{2}$$

the quadratic Volterra model yields an expression for slow drift vessel response comprised of mean and low frequency terms:

$$D(t) = \frac{1}{2}\left\{a_1^2 \cdot G_2(\omega_1, -\omega_1) + a_2^2 \cdot G_2(\omega_2, -\omega_2)\right\} + \mathrm{Re}\left\{a_1 a_2 \cdot G_2(\omega_1, -\omega_2) \cdot e^{i(\omega_1 - \omega_2)t}\right\} \tag{3}$$

where a_1, a_2 are dual wave component amplitudes and G_2 is the QFRF for drift force or motion.

Consider the slow surge drift motion of a soft, linearly moored vessel excited by low-frequency second-order forces resulting from dual wave and vessel interaction. For this type of vessel/mooring system, the low-frequency response will be represented in the lower octant of the bi-frequency domain, where ω_2 is always negative and ω_1 is always positive. Hence, $\Omega_1 = \omega_1 + |\omega_2|$ and $\Omega_2 = \omega_1 - |\omega_2|$ and will hereafter be referred to as sum and difference frequencies, respectively.

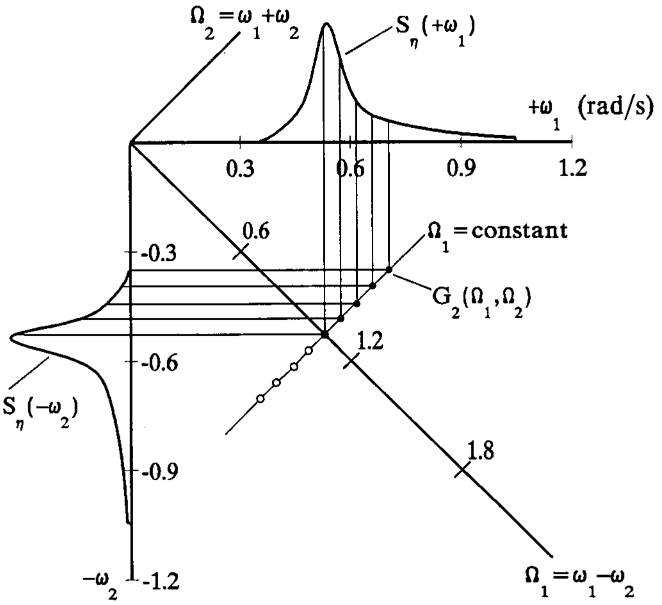

Fig. 1 Mapping of bi-frequency plane

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