International Journal of Offshore and Polar Engineering
Vol. 2, No. 3, September 1992 (ISSN 1053-5381)

Surge Drift Motion of a Moored Vessel in Random Waves

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ABSTRACT

Experimental measurements of the surge drift motion of a soft-moored barge in random waves are compared to a numerical simulation employing a complete quadratic frequency response function for surge motion. Simulations are based on a Volterra theory and experimentally determined bi-frequency wave drift damping coefficients. Estimates of typical statistical parameters derived from a large ensemble of model tests and numerical simulations are found to be in good agreement, and illustrate the weakly non-Gaussian nature of the surge response to Gaussian wave excitation.

INTRODUCTION

The response of moored offshore structures to random seas is often dominated by large amplitude longitudinal and lateral motions with frequencies significantly lower than the frequency range of the individual waves. Preliminary sizing and performance analyses of such soft-moored systems require reliable estimates of the composite effects of the low- and wave-frequency response for determination of mean, maximum and significant excursions and mooring line loads, as well as induced motions and loads on ancillary components such as drill strings or product risers.

Slow drift motion of a moored vessel in random waves has often been predicted in the time domain by solving iteratively an equation of motion requiring the input of appropriate damping coefficients and drift force excitation. For example, Kim and Breslin (1976) developed a time domain simulation for surge drift motion of a moored ship in random seas in which the equation of motion included theoretically estimated drift force and an arbitrarily assumed damping coefficient.

The aforementioned approach was improved by Wichers (1982) through the introduction of experimentally determined viscous and mean wave drift damping terms into the equation of drift motion. Mean wave drift damping coefficients were obtained from a series of free-oscillation tests in monochromatic waves, and subsequently used to determine a single statistical mean wave drift damping coefficient for a given random sea condition.

Kinoshita and Takaiwa (1990) performed time domain simulations and experimental measurements of the surge drift motion of moored structures in dual (bichromatic) and random waves. Various surge drift hydrodynamic forces were obtained from both free- and forced-oscillation tests in monochromatic waves. Time varying wave drift damping and constant wave drift damping, for use in simulations in random sea conditions, were calculated using the mean wave drift damping measured in monochromatic waves. The relative importance of slowly varying added mass and damping was investigated by carrying out simulations in which combinations of these hydrodynamic terms were approximated as time varying, constant or zero.

Krafft and Kim (1990) investigated the complete quadratic frequency response function (QFRF) for surge drift motion of a soft-moored barge in dual waves. Bifrequency wave drift damping coefficients were determined from free-oscillation tests in dual waves, the difference frequency of which was identical to the moored-barge surge resonance frequency. Assuming that the surge drift oscillation system is linear and driven by second-order drift force, the experimentally determined damping coefficients and theoretically calculated wave drift force QFRF were used to obtain the QFRF for surge drift oscillation. A comparison of the predicted motion QFRF with experimental data yielded good agreement. Subsequent comparisons of experimental data with the QFRF predicted using mean wave drift damping generally provided poor agreement, thus confirming the importance of wave drift damping with respect to low-frequency motions.

In the present investigation, the foregoing QFRF is used in the simulation of the surge drift motion of the same shallow-drafted, linearly moored barge in random seas through the application of a quadratically nonlinear Volterra functional polynomial model. The results of this numerical simulation are compared with experimental measurements in terms of a variety of conventional statistical parameters.

QUADRATIC VOLTERRA MODEL

The Volterra functional polynomial up to the second order is written:

$$D(t)=\int g_1(\tau_1)\,\eta(t-\tau_1)\,d\tau_1 + \iint g_2(\tau_1,\tau_2)\,\eta(t-\tau_1)\,\eta(t-\tau_2)\,d\tau_1 d\tau_2 \qquad (1)$$

The linear and quadratic impulse response functions, LIRF and QIRF, are related to the linear and quadratic frequency response functions, LFRF and QFRF, as follows:

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Received April 1, 1991: revised manuscript received by the editors May 4, 1992. The original version (prior to the final revised manuscript) was presented at The First International Offshore and Polar Engineering Conference (ISOPE-91), Edinburgh, United Kingdom, August 11-16, 1991.

KEY WORDS: Quadratic frequency response function, random waves, surge drift motion, Volterra model, wave drift damping.