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Springing and Ringing Due to Laboratory-Generated Asymmetric Waves

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ABSTRACT

Three typical asymmetric waves were generated repeatedly for the measurement and estimation of forces of a TLP. A model for prediction of the forces on columns and pontoons was employed to predict the wave moment of component structure. The resultant forces and moment time series are used to simulate the nonlinear response motions and tether tensions. The tension spectrums around the resonance frequencies are filtered to observe the tension behaviors. Strong and weak asymmetric waves respectively produced impact and nonimpact on the platform and ringing and springing in tendons.

INTRODUCTION

It is our objective to find the springing and ringing in the tethers of the ISSC-TLP due to laboratory-generated asymmetric waves.

Ringing is a high-frequency structural response in the form of a transient energetic burst, and it is understood as a natural frequency response of the structure due to weak impact, caused by steep asymmetric nonbreaking waves (Natvig,1994; Davies et al., 1994; and Jefferys et al., 1994). No numerical techniques are currently available for simulation of such waves but they can be generated in wave tanks.

Our approach consists of the following 4 steps: generate the asymmetric waves in a 2-D wave tank; measure the wave forces of components of the structure and estimate the resultant forces and moment; use the resultant forces to simulate the TLP response including the tether tensions; and analyze the tensions to find the springing and ringing.

The techniques needed for the present study have already been developed: a simulation code of nonlinear TLP response to random seas (Kim et al., 1994a); the generation of strong and weak asymmetric waves in a wave tank (Kim et al., 1992) and measurement of the impact and nonimpact on a vertical truncated cylinder due to the asymmetric waves (Zou and Kim, 1995); an empirical model to predict the impact on the vertical truncated cylinder (Kim et al., 1996).

Thus the major work involved here is to estimate the resultant forces and moment of the TLP platform fixed in longitudinal waves. Wave forces of component structures of the TLP are measured and added to determine the resultant forces and moment. Because no moment gauge is currently employed, the moments of component structures are predicted using the prediction model and measured forces of component structures.

The maxima of the simulated time series of the tether tensions near the natural frequencies are 2.0 MN, 5.0 MN and 17 MN. The first two tensions are due to the weak asymmetric waves while the last is due to the strong asymmetric wave. The first two are springing, while the last is ringing.

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KEY WORDS: Stokes 5th-order-like regular wave, strong and weak asymmetric wave, impact and nonimpact, springing and ringing.

The estimation of forces and viscous dampings in Kim et al. (1995) has been improved in the present work.

TEST FACILITIES

The wave tank is 37 m long, 0.91 m wide, and 1.22 m deep and is equipped with a Commercial Hydraulic RSW 90-85 dry-back, hinged-flap wave maker, and a downstream wave energy-absorbing beach. The stillwater depth is kept constant at 0.80 m, and Froude law is applied with a length scale ratio of 1/100.

Resistance-type wave gauges are used to measure wave surface elevations. The accuracy of the wave gauge is +/-0.1 cm.

A laser Doppler anemometer system is employed to measure the wave particle velocities near the wave surface. A 3-beam laser system consists of an INNOVA 4-watt argon-ion laser and DANTEC optics, transverse mechanism, and a frequency tracker and a shifter for each velocity component. Accuracy of the LDA is +/-0.005 m/s for 10-100 kHz range and +/-0.02 m/s for 33-333 kHz range.

The wave force is measured by an ARCTEC strain gauge platform with a capacity of 178 N and an accuracy of +/-1% of the applied force.

The principal data collection and processing system consists of a Hewlett Packard HP-3852A data acquisition system and an HP 330 controller. The driving signal for the wave flap is produced by a software package developed by Krafft et al. (1987) and LDA measurement uses a software developed by Boo et al. (1990).

ASYMMETRIC WAVES

Typical records of model storm seas consist of nonlinear asymmetric waves, i.e., the crest heights are larger than the trough heights and the waves are asymmetric about the vertical axes through the crests. The storm waves are asymmetric about the horizontal axis (MWL) as well as vertical axes through the crests.

Asymmetries about the vertical axis are measured by the rise and fall time of the crest and its concaveness and convexness. The highly nonlinear wave given by Longuet-Higgins and Cokelet (1976) is a strong asymmetric wave with distinct concaveness in the front and convexness in the back of the crest. The highly nonlinear wave due to Schwartz (1974) is asymmetric about MWL and a strong nonlinear wave, with equal and distinct concave front and concave back in the crest.

Usually the laboratory asymmetric waves have negligibly small concaveness and/or convexness in the crest. These waves are named weak asymmetric waves. It is difficult to generate strong