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Ringing of ISSC TLP Due to Laboratory Storm Seas

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ABSTRACT

A strong asymmetric wave is generated by a control in an irregular wave train of a laboratory high sea. The measured forces of the ISSC TLP model due to such asymmetric waves, and second-order theoretical forces, are used to simulate nonlinear responses including springing and ringing. Statistical analyses reveal that springing is due to weak asymmetric waves while ringing is due to the strong asymmetric wave. The second-order force produces springing only, and its maximum high-frequency tension is about 4% of that due to the measured forces in the equivalent sea.

INTRODUCTION

It is well known that tendon fatigues are due to high-frequency tensions being generated by the high-frequency resonant motions of the platform. Ringing occurs similarly at the high resonance frequencies, but appears to be extremely bursting and transient. This particular behavior is understood to be due to impulsive horizontal force (Natvig, 1994). From extensive experimental studies (Zou and Kim, 1996; Kim et al., 1997a; Kim et al., 1997b) we found that the impulsive load can be generated only by strong asymmetric waves. And the impulsive forces including other measured forces have force amplitudes of significant size in the high-frequency region, while the second-order wave forces have negligibly small amplitudes.

The transient waves are evidently strong asymmetric, and generate the horizontal impact and ringing (Kim et al., 1997). However, the above transient data do not provide a long enough time history for statistical analyses. Hence we have generated a storm sea 27 min long containing a strong asymmetric wave, and measured the forces of the TLP model.

The study follows 4 steps, i.e., generate a strong asymmetric wave in the irregular wave train; measure the wave forces including impact of the TLP model; simulate the nonlinear response of the coupled TLP system due to the measured forces; statistically analyze the tether tensions.

The waves, winds and currents are the environmental elements on the TLP system. However, the present investigation considers only the wave loads in order to compare the effects of both theoretical and experimental wave loads. We employ the second-order theoretical forces (Liu et al., 1995) to compare the responses to those of measured forces in the sea of equivalent energy spectrum.

The analysis reveals that the strong asymmetric wave in a storm sea causes a weak impact and ringing, while the weak asymmetric waves in the other storm seas create only springing. The second-order theoretical wave force produces springing only, and the maximum high-frequency tension is about 4% of the result due to the measured force of the equivalent sea (wave 2).

A similar work was performed by Zou et al. (1997). The difference is that the present work has measured the moment and generated 3 new different storm seas, which are slightly weaker than those in the previous work.

STRONG AND WEAK ASYMMETRIC WAVES IN IRREGULAR WAVE TRAIN

The theoretical wave by Longuet-Higgins and Cokelet (1976) is highly nonlinear and asymmetric. The crest of the wave has a distinct concave front and a convex rear. Thus the wave may be called a strong asymmetric wave. Those without the above property are weak asymmetric waves. The transient waves are strong asymmetric (Kim et al., 1992; Zou and Kim, 1996; Kim et al., 1997a, 1997b), whereas most conventional laboratory waves are weak asymmetric.

A strong asymmetric wave group similar to the transient wave can be built through a control in the irregular wave train. Funke et al. (1982) proposed a distortion technique to generate such asymmetric irregular waves. A similar approach is used here to locally distort the largest wave group in the time domain. (See Appendix A.)

Myrhaug and Kjeldsen (1984) analyzed field data and found that the vertical asymmetry parameter of the waves varied from 1.2 to 2.1. This can be used as a criterion of strong asymmetric waves. The above confirms that there are wind-driven strong asymmetric waves in the real ocean.

The strong asymmetric wave can be precisely quantified by imposing the criterion of vertical asymmetry and the condition of the crest to have a concave front and a convex back. Such a strong asymmetric wave is found in the 3-h-long wave record of MARINTEK (Statoil, 1996). This strong asymmetric wave looks similar to that generated by the control in our wave tank, as shown in Fig. 1. The parameters of JONSWAP spectrums adopted by MARINTEK and Texas A&M University (Isherwood, 1987) are Hs (m) =15.4 and 9.88; Tp (s) = 17.8 and 11.02; Gamma = 1.7 and 6.5. The vertical asymmetry parameters of MARINTEK and TAMU are 1.50 and 2.15, which indicate that the TAMU wave has a higher vertical asymmetry. It is easy to

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KEY WORDS: Springing and ringing, second-order forces, strong and weak asymmetric waves, impact, ISSC TLP, tendon fatigues.