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Recent Progress in Springing and Ringing Research - A Review

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ABSTRACT

This paper presents a review of recent studies of tether ringing of TLP. It includes strong and weak asymmetric waves, method of tendon analysis, physical model test and simulation of ringing, physical experiment and model of ringing wave, and physical experiment and model of ringing loads. However, it excludes the effect of tendon dynamics on ringing research.

KEYWORDS: springing and ringing, ringing wave, ringing load, ringing indicator, strong and weak asymmetric wave, Morison and diffraction model.

INTRODUCTION

Steep and large waves produce nonlinear motion and tether tension of TLP, while tension is distributed in the low-, wave- and high-frequency region. The tension near the pitch resonance frequency is high frequency tension (HFT), which consists of pure springing or ringing in springing, the latter of which is supposed to occur due to weak wave impact on columns of TLP. Springing is steady, while ringing is transient or burst. The resonance frequency depends on the design of TLP and usually falls in the region well above the prime wave frequencies, i.e. about 1.2 rad/s to 3.7 rad/s or at the period of 5.2 s to 1.7 s. Thus, the nonlinear high frequency wave and corresponding nonlinear high frequency force are totally responsible for tether ringing. Springing and ringing were found in Hutton TLP in the storm seas. Similar phenomena were observed in the model test of Heidrun TLP in MARINTEK. The finding of ringing in the model test gave an impetus to Norwegian TLP industry to conduct nonlinear hydrodynamics research. The waves that produced ringing in Heidrun TLP were regenerated in a long and wide wave tank to measure the horizontal forces and moments of single columns of different diameters. The data have been utilized for verification of ringing load models.

In Norway, design of TLP and GBS (gravity base structure) with dynamic response periods lower than the periods associated with the major part of the wave energy, i.e. below 5-6 s, must consider ringing loads but above, say 1-2 s. On the other hand, tether ringing has never been discovered in the Gulf of Mexico. The model tests of TLPs to be installed in the Gulf of Mexico did not find tether ringing either.

STRONG AND WEAK ASYMMETRIC WAVE

Mathematical waves are usually classified as to be linear, weakly nonlinear and highly (or strongly) nonlinear. A sinusoidal wave and sum of many sinusoids with random phase angles are linear. Given a number of sinusoidal waves, one creates 2nd or 3rd order nonlinear irregular waves (Longuet-Higgins, 1963; Pierson, 1993), which are weakly nonlinear higher-order waves. Stokes higher-order regular waves are weakly nonlinear. A highly nonlinear mathematical wave was created by Schwartz (1974) which is symmetric with respect to the vertical axis through the crest, and asymmetric about the horizontal axis.

It was necessary to use new terms "weak and strong asymmetric wave" in dealing with laboratory or field waves. Nonlinear waves are generally asymmetric about the horizontal (MWL) axis as well as about vertical axes through crests and troughs, whereas the linear wave is symmetric about both axes. Longuet-Higgins and Cokelet (1976) numerically generated a "highly nonlinear wave" whose crest has a distinct convex front and a concave rear, and has a strong vertical asymmetry as well as horizontal asymmetry. We call the above highly nonlinear wave "strong asymmetric wave." The vertical asymmetry is expressed by asymmetry parameter, the ratio of the falling to rising period of the crest, field data of which varies from 1.2 to 2.1 (Myrhaug and Kjeldsen, 1984).

All the other waves which do not have the above property are "weak asymmetric." All the perturbation-based wave theories give weak asymmetric waves.

A typical ringing wave generated in wave tank in MARINTEK is shown in Fig. 1a, where the largest wave group is regarded as one of ringing wave events. Zou et al (1998) found a strong asymmetric wave in the above 3-hour long wave as shown in Fig. 1b. The above authors also generated a storm sea containing a strong asymmetric wave (Fig. 2a) applying a local distortion similar to Funke et al (1982), i.e., given the wave energy spectrum, one generates Gaussian (linear) wave elevation time series which usually contains large wave groups. The largest wave group is deformed to become a strong asymmetric wave. Applying FFT to the modified time series, one