

Simulation of Draupner Freak Wave Impact Force on a Vertical Truncated Cylinder

Nungsoo Kim and Cheung Hun Kim*
Civil Engineering Department, Texas A&M University, College Station, Texas, USA

ABSTRACT

In the authors' previous work, a Draupner freak wave was produced in the wave tank, and the particle velocities and wave impact force on a vertical truncated cylinder were measured. This paper presents simulations of the impact forces and wave kinematics and compares them with the experimental data. In addition, high-frequency components contained in the impact force and freak wave have been examined by continuous wavelet transform. The large high-frequency components make the freak wave and impact force strongly nonlinear. The simulated impact force due to the field (Draupner) wave is slightly lower than that of the laboratory freak wave. The freak wave impact forces are nearly the same as those of the previously studied extreme transient waves.

INTRODUCTION

The authors have previously reproduced the Draupner freak wave in the wave flume and measured the particle horizontal velocity field and wave impact force, placing the cylinder against the freak wave so as to obtain the maximum horizontal force (Kim and Kim, 2003). The impact force was found to be similar to those of the extreme transient waves (TW) produced at the same wave flume (Kim et al., 1997).

In fact, 2 methods of simulation have been studied. One is a diffraction force method with transfer function involving the measured time history of surface displacement; the other is the basic Morison force method with water particle motion determined numerically from the time history of surface displacement. For convenience, we may simply call the 2 methods the diffraction method and the Morison method, although a universal nonlinear input output model (UNIOM) was involved in both methods.

The Morison method was successfully used for the simulation of the transient wave impact force in Kim et al. (1977). The diffraction method was first applied by Kim and Zou (1998) for simulating the horizontal force on a vertical truncated column measured by Stansberg et al. (1995). In the above works, the diffraction method was found to have agreed better than the Morison method over the entire time series. The diffraction method was further successfully applied to simulate steep random wave forces on a fixed column (Kim and Wang, 1999) and the ringing wave load on the Heidrun TLP (Kumar and Kim, 2002). These reasons led to the decision to investigate both methods for simulation.

In this study, the diffraction method was found to have shown excellent agreement except for the impact force during the time interval between 5.5 s and 6.5 s. The reason for the failure was investigated with wavelet analysis.

Jacobsen et al. (2001) have looked into the hidden high-magnitude and high-frequency wave components during the peaking of the Draupner freak wave. Kishimoto et al. (1995) carried out a search of high structural stresses employing the Gabor wavelet transform. Similarly, we have employed the Gabor wavelet for determining the magnitude and frequencies hidden in the impact force as well as the freak wave time series.

The Morison method (Kim et al., 1997) can simulate the horizontal particle velocities of the freak wave in the time domain by UNIOM, and calculate the impact force integrating the Morison equation. This approach has been successfully applied in this research, as it was in the previous work with the transient wave. The highly nonlinear wave kinematics of the freak wave produce the high acceleration and consequently the large impact force during the rise of the peak of the freak wave.

The structure used here is the same truncated column tested in the wave tank in the previous work. It was made of a plastic tube 6 mm in thickness; the diameter and draft were 0.1 m and 0.3 m, respectively. The depth of the water is 0.8 m. A scale of 1/100 is assumed in applying the Froude similitude law.

Fig. 1 shows the field freak wave (FFW) and the laboratory freak wave (LFW) together (Kim and Kim, 2003).

UNIOM FOR SIMULATION OF WAVE FORCE

The universal nonlinear input output model (UNIOM) uses the measured nonlinear wave elevation time series (Fig. 1) as the

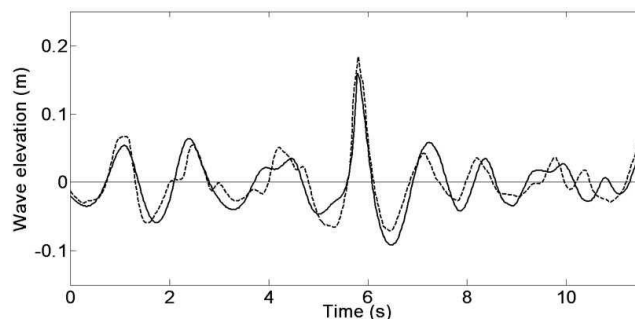


Fig. 1 Laboratory Draupner freak wave of 12 s (solid line), Draupner freak wave of 12 s (dotted line), both in model scale

*ISOPE Member.

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KEY WORDS: Field freak wave, laboratory freak wave, transient wave, freak wave kinematics, wave impact force, simulation of impact force, wavelet transform, universal nonlinear input output model, linear transfer function, quadratic transfer function.