The Statistical Characteristics of Wave Forces on Vertical Cylinder
by a Maximum Entropy Method

Yangyang Gao, Dingyong Yu, Zhengshou Chen and Cuilin Li
College of Engineering, Ocean University of China
Qingdao, Shandong, China

Wei Feng
School of Water Conservancy, Changsha University of Science & Technology
Changsha, Hunan, China

ABSTRACT
A newly developed maximum entropy method has been introduced to analysis the statistical characters of wave forces distribution in shallow water subject to random wave. The relationships between significant wave pressure and significant wave height are manifested. The results indicate that the well-designed maximum entropy distribution is consistent with the experimental data fairly well, superior to other widely used probability density functions.

KEY WORDS: Maximum entropy method; wave forces; shallow water area; vertical cylinder.

INTRODUCTION
As an important branch of water wave mechanics, how to determinate the forces induced by waves to fixed and compliant structures, as well as the motions of floating objects have attracted much attention in the past few decades (Dean and Dalrymple, 1998). As is well known, the objects, whether floating on the sea or attached to the bottom, are subject to wave forces more or less, therefore the attempt to predict the random wave forces accurately in the design of offshore structures become important and meaningful. Numerous studies have been done for wave forces imposed on vertical cylinders. Most research works focused on the interaction between fluid flow and cylindrical structures based on the Morison equation (such as Chaplin et al., 1993; Song, 2005, etc). According to the linear theorem of wind-generated waves (Longuet-Higgins, 1963; Philips, 1967), the linear Froude-Krylov force, whether on a vertical cylinder or on a horizontal submerged cylinder, can be expressed as a random Gaussian process in time domain. In fact, since the ocean wave process is essentially nonlinear (non-Gaussian), the omission of nonlinearity will distinctly reduce the accuracy of wave forces estimation. So far, the statistics approaches to wave forces analysis can be divided into to main aspects: the theoretical distribution based on the random wave model (Song et al., 2000, etc) and the statistical distribution. Yu et al.(1991) proposed that the peak value of wave force is fit for Weibull distribution in case of large $K_e$ numbers, and trends to Rayleigh distribution in case of small $K_e$ numbers, based on the analysis of the distribution of the instantaneous incline force of irregular wave. Naess and Johnsen (1992) introduced a numerical way to calculate the probability density function of the second-order hydrodynamic loads and the response of compliant offshore structures. From the model test about irregular breaking wave forces on vertical walls carried out by Li (1995), it indicates that the wave force distribution can be expressed by Weibull formulation, according to the least square method. Kyte (1996) found that the peak force values in each irregular wave series are fit to a three parameter Weibull distribution according to the moment method, when investigated the wave force on vertical cylinders upon shoals, made tests with long crested waves. Arena and Fedele (2003) investigated the statistical properties of the second-order Froude-Krylov force on a cylinder for narrow-band spectra, and proposed that the predictions for the Froude-Krylov force on a horizontal submerged cylinder agree with the results of small-scale field experiment.

Despite the developments of nonlinear theories, few methods about the statistic distribution of observed wave forces have been provided. Although the well-known Weibull distribution has been widely applied to the wave force distribution analysis, the major difficulty is to estimate its parameters, for the prior assignment of such a distribution is a priori. In this case, a non-Rayleigh distribution is required for nonlinear wave forces. With the advantage of its acquisition under the maximum uncertainty, the maximum entropy principle has been successfully used to derive statistical distribution of wave heights in both finite water depth and random wave field (Ahn, 2000; Zhou and Xu, 2004a; Chen and Wang, 2007), the annual extreme wave heights (Xu and Zhang, 2004b), surface elevation of nonlinear sea waves (Zhang and Xu, 2005). Moreover, Yu (2007) applied the maximum entropy method to the statistical distribution of wave group. In this article, a probability density function for wave force according to the maximum entropy principle has been introduced to analyze the statistical characteristics of wave force acting on a vertical cylinder in shallow water area.

The main purpose of this paper is to provide a statistic distribution for wave forces subjected to the random waves. Based on the maximum entropy probability function for the surface elevation of nonlinear sea waves suggested by Zhang (2005), the statistic distribution of wave forces using the maximum entropy method is described. In section 2, the maximum entropy distribution is stated; in section 3, experimental