Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference
Lisbon, Portugal, July 1-6, 2007

ISBN 978-1-880653-68-5; ISBN 1-880653-68-0(Set); ISSN 1098-6189 (Set)

Spectral Analysis and Applications of Shallow Water Waves

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ABSTRACT

The spectral analysis of nonlinear random waves in shallow waters is carried out in this paper by theoretical and numerical methods. This is done by expressing nonlinear wave profile as nonlinear combination of the first order wave component. Under the assumption of the first order wave component being zero-mean Gaussian processes, the relationship between autocorrelation functions of wave profile and the first order wave component is established using the nonlinear spectral analysis. The spectral densities of nonlinear random waves are then obtained. An experience formula is proposed for estimating wave spectra in shallow waters by numerical method. The wave force spectrum is calculated by using the results of the analysis to show the applications of the method.

KEY WORDS: Spectral analysis; nonlinear waves; shallow waters; wave forces

NOMENCLATURE

A	spectral intensity factor
A_d , A_I	force coefficients
a, b	parameters
C_d , C_m	Drag and inertial coefficients
D	diameter of cylinder
d	water depth
$E[\cdot]$	mean of the random process involved
f	wave force per unit length
g	gravity acceleration
H_s	significant wave height
h_1 h_2 h_3	parameters
k	wave number
k	modulus of elliptic intgrals
p_1 - p_6	parameters
R	autocorrelation function of random process involved
S	spectral density of random process involved
s	vertical coordinate
T	wave period
t	time
u	velocity of water particles
α, β	parameters
η	wave profile
σ	root mean square of involved variable
τ	time lag
ω	circular frequency of waves
ω_0	crest frequency of wave spectrum
ζ	the first order wave component

INTRODUCTION

With the development of offshore oil exploration and exploitation, a large number of offshore structures have been constructed. Some of them were built in the shallow waters. Several offshore structures built in Chinese Bohai Bay in the past few years crushed in the wave forces, though the calculated wave forces on the structures are relatively small. This fact results in active researches for the wave force calculation in shallow waters.

The offshore structures serviced in offshore environment will endure to enormous environment loadings. Since the sea waves are of random property, the stress in the structures induced by the waves is alternated. The fatigue strength and fatigue life of the structures will be suffering from severe threat. It is well known that the random sea wave spectrum is the basis to the dynamic responses, stress in structures and fatigue life estimation of offshore structures in random sea waves. Therefore, the properties of random waves have been being studied by a quite number of offshore engineering researchers (Chuntao, 1996, Beji, 1999). Previous studies indicated that for small amplitude waves, the spectral properties can be studied by linear method. As far as the shallow water waves are concerned, however, the linear assumption is no longer suitable. That is to say, the spectral densities of shallow water

[1]Project supported by Key Subject Research Foundation of Shandong Province.