PROCEEDINGS
OF THE CONFERENCE OF GLOBAL CHINESE SCHOLARS ON HYDRODYNAMICS

全球华人水动力学学术会议论文集

Editor-in-Chief: Zhu De-xiang
Zhou Lian-di
Yang Xian-cheng

SHANGHAI UNIVERSITY PRESS
上海大学出版社

全球华人水动力学学术会议论文集

PROCEEDINGS OF THE CONFERENCE OF GLOBAL CHINESE SCHOLARS ON HYDRODYNAMICS

Editor-in-Chief

Zhu De-xiang
Zhou Lian-di
Yang Xian-cheng

上海大学出版社

Shanghai University Press

图书在版编目（CIP）数据

全球华人水动力学学术会议论文集/朱德祥，周连第，杨显成主编.—上海：上海大学出版社，2006.7

ISBN 7-81058-978-4

I.全... II.(1)朱...(2)周...(3)杨...III 水动力学—学术会议—文集—英文 IV.TV131.2-53

中国版本图书馆 CIP 数据核字(2006) 第 075177 号

Responsible Editors:

Wang Yue-sheng (王悦生)

Zhao Gang (赵 钢)

Cover Designer:

Ke Guo-fu (柯国富)

Published by Shanghai University Press, Shanghai, China

ISBN 7-81058-978-4/TV·001

Price: 150.00

Technical Advisory Committee

Chairman:

DONG Shitang	(Wuxi, China)

Members:

BIAN Yingui	(Beijing, China)
CAI Shutang	(Shanghai, China)
CHEN Yaosong	(Beijing, China)
CHIEN Weizang	(Shanghai, China)
CHWANG Allent T.	(Hong Kong, China)
DAI Yishan	(Harbin, China)
HE Yousheng	(Shanghai, china)
HUI Waihow	(Hong Kong, China)
LIANG Zaichao	(Wuhan, China)
LIN Chia-chiao	(Cambridge, U.S.A.)
LING Sung-ching	(Silver Spring, U.S.A.)
LIU Gaolian	(Shanghai, China)
MEI Chiang C.	(Cambridge, U.S.A.)
QIU Dahong	(Dalian, China)
SONG Charles C.S	(Minnisota, U.S.A.)
WU Deming	(Harbin, China)
WU Theodore Y.	(Cambridge, U.S.A.)
WU Xiuheng	(Wuhan, China)
XU Zhenfang	(Beijing, China)
XU Xieqing	(Beijing, China)
YAN Kai	(Nanjing, China)
ZHAN Zhaoshun	(Beijing, China)
ZHAO Wenqian	(Chengdu, China)
ZHENG Qingcun	(Beijing, China)
ZHOU Heng	(Tianjin, China)
ZHUANG Lixian	(Hefei, China)
OU Shan-hwei	(Tainan, China)

Organizing Committee

Chairman:

WU Yousheng	(Wuxi, China)

Vice Chairmen:

DAI Shiqiang	(Shanghai, China)
DONG Shitang	(Wuxi, China)
MIAO Guoping	(Shanghai, China)
ZHU Dexiang	(Shanghai, China)

Members:

CAI Daming	(Wuxi, China)
CHEN Hamnching	(Texas, U.S.A.)
CHEN Xiaobo	(Paris, France)
CHENG Liang	(West Australia, Australia)
CUI Weicheng	(Wuxi, China)
CUI Haiqing	(Daqing,China)
DAI Huihui	(Hong Kong, China)
DUAN Wenyang	(Harbin, China)
HUANG Guangwei	(Tokyo, Japan)
HUANG Shan	(Glasgow, U.K.)
HUAI Wenxin	(Wuhan, China)
JIANG Tao	(Duisburg, Germany)

PREFACE

When we are entering the 21st century, along with the growth of global economy, especially in the variety of fields, such as naval architecture, ocean and coastal engineering, hydraulic and hydropower engineering, environment engineering, agriculture engineering, biochemical and biomedical engineering, the interest in the science and technology of hydrodynamics, one of the most important branches of theoretical and experimental fluid mechanics, grows faster than ever before. Great progress in the theoretical, computational and experimental hydrodynamics was achieved during the past decades by the efforts of the scientists and specialists working in the field all over the world, among which contributions made by Chinese scholars at home and abroad have attracted even more prominent attentions.

Chinese nation is of the long history of 5000 years, in which there were full of inspiring and prosperous cultural and scientific achievements. Dated back hundreds years ago, the famous Du-Jiang weir of Li Bing in Sichuan, the great freight of Zheng He sailing round the vast oceans were two of the brilliant examples of Chinese innovative achievements in the field of hydrodynamics. In the new era of a developing China, the Three Gorges Dam and Hydropower Station, the blooming shipbuilding industry reaching the third largest one in the world since 1996 etc., to just mention a few, are the examples of the achievements in research and applications of modern hydrodynamics.

To encourage the exchange of knowledge and to promote the levels of research, development and application of hydrodynamics in multidisciplinary fields for better fitting in the needs of the rapid economy growth, late Professor Gu Maoxiang and a group of specialists, representing all those in the country working in the field of hydrodynamics, initiated the idea, set up the editorial board and started the publication of "***Journal of Hydrodynamics***" in 1986. Since then for 19 years, organized by the Editorial Board of the Journal, the annual "***National Conference on Hydrodynamics***" has been held in series in the mainland of China, Hong Kong and Macao. The successful journal and the annual conferences have been widely and warmly responded and strongly supported by Chinese scholars at home and abroad. This makes one of the most vivid activities of scientific and technical exchange in China. At present over 30 famous over sea Chinese scholars are the members of the Editorial Board of the Journal. In 1994, the Editorial Board of the Journal also initiated the "***International Conference on Hydrodynamics***". It is now an international conference held worldwide every two years under the supervision of well-known scholars and organizations from different countries, regions and nations.

On the occasion of celebrating the 20th anniversary of the ***Journal of Hydrodynamics***, the **Conference of Global Chinese Scholars on Hydrodynamics** is held to provide an opportunity for gathering together the Chinese scholars from different parts of the world to present their latest research achievements and to stimulate the discussions of important topics in the relevant areas of hydrodynamics.

This conference is jointly organized and sponsored by the **Editorial Board of *Journal of Hydrodynamics***, **Chinese Society of Theoretical and Applied Mechanics**, **Chinese Society of Naval Architects and Marine Engineers**, **Chinese Hydraulic Engineering Society**, **Chinese Society of Oceanography**, and also supported by China Ship Scientific Research Center, Shanghai Jiaotong University, Shanghai Institute of Applied Mathematics and Mechanics, the First Institute of Oceanography of the State Ocean Administration, Shanghai Society of Theoretical and Applied Mechanics, Daqing Petroleum Institute and National Laboratory of Hydrodynamics, China.

The present proceedings contain 87 papers being presented at the conference. You may find from the contents and authors of the papers that the conference will surly be creative and productive, and the meeting will definitely be a great event for Chinese scholars. On behalf of the Organizing Committee I would like to thank all the participants for their great contributions to the successful conference, and all the supporting organizations listed above.

Had been devoted for nearly half century to the research and development of hydrodynamics in China, Professor Gu Maoxiang left us 10 years ago. By holding this conference we also deeply cherish the memory of late Professor Gu for his great technical achievements and outstanding personality.

Wu You-sheng

Chairman of CCSH'06 Organizing Committee

July 8, 2006, Wuxi, China

CONTENTS

Keynote Lectures

Session A1

Session B1

Session A2

Session B2

Session A3

Session B3

Session A4

Session B4

Session B6

Session A7

Session B7

Session A8

Session B8

Keynote Lectures

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

Conference of Global Chinese Scholars on Hydrodynamics

LONG-PERIOD OSCILLATIONS IN A HARBOR EXCITED BY BROAD-BANDED RANDOM SEA WAVES

CHEN Mengyi, MEI Chiang-chung

Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA, 02139, USA E-mail : ccmei@mit.edu

KEY WORDS: Random sea waves, nonlinear water waves, nonlinear resonance, harbor resonance, nonlinear scattering, nonlinear diffraction, slow-drift oscillations

1. Introduction

In designing the dynamic positioning systems for floating oil rigs or the mooring systems for ships and tankers, it is important to predict their oscillations at long periods in the range of one to several minutes. Forced oscillations in this period range can excite natural modes of the mooring system, and cause excessive strain and breakage of mooring lines. Semi- enclosed harbors also possess natural modes of long periods. If resonance occurs, strong current appears at the narrow entrance, creating hazards for small boats. Excessive sways of tankers or large vessels inside a harbor can slow down the loading and unloading operations, resulting in economic losses. Since many of the affected harbors are free from the threat of long-period tsunamis, but are often attacked by storm-generated short waves, harbor oscillations at long periods can only be induced by nonlinearity. Past theories on this topic are limited to narrow-banded and deterministic incident waves [1,2,3]. A new theory for broaded-banded random waves is needed.

For two-dimensional standing waves in deep water, Sclavounos[4] has advanced a systematic stochastic theory for calculating the nonlinear contributions to the wave spectrum. He showed that the nonlinear contribution starts at the fourth order in wave steepness, and involves the frequency responses at first, second and third orders. We shall first extend his theory to more complex waves involving scattering, and then point out that long-period harbor spectra can be predicted by using just the second-order frequency response. Aided by our recent work on second-order mild-slope approximation [5], calculation of the nonlinear spectrum is greatly simplified. Sample numerical results are discussed for a square harbor of constant depth.

2. The Second-Order Problem

For waves of length comparable to depth, the flow field is fully three-dimensional. Let us expand the velocity potential and free-surface height in powers of the wave steepness $\varepsilon = O(kA)$

$$\Phi = \Phi_1 + \Phi_2 + ..., \qquad \varsigma = \varsigma_1 + \varsigma_2 + ... \tag{1}$$

where the subscripts indicate the order of magnitude in powers of ε . Let the horizontal and three-dimensional gradient operators be distinguished by ∇ and ∇_3 respectively. At each order, Φ satisfies the Laplace equation

$$\left(\nabla^2 + \frac{\partial^2}{\partial z^2}\right)\Phi_j = 0, \qquad j = 1,2,3,... \tag{2}$$

in the fluid, and

$$\frac{\partial \Phi_j}{\partial z} = \nabla h \cdot \nabla \Phi_j, \qquad z = -h(x,y) \tag{3}$$

$j = 1,2,3,...$ on the sloping seabed. All lateral boundaries are assumed for simplicity to be vertical throughout the depth, hence

$$\frac{\partial \Phi_j}{\partial n} = 0, \qquad j = 1,2,3,... \tag{4}$$

where the unit normal $\vec{n}$ is in the horizontal plane. On the still water surface, $z = 0$, the boundary condition for the first-order potential is homogeneous

$$g\frac{\partial \Phi_1}{\partial z} + \frac{\partial^2 \Phi_1}{\partial t^2} = 0, \qquad z = 0. \tag{5}$$

while that for the second-order potential is not

$$g\frac{\partial \Phi_2}{\partial z}+\frac{\partial^2 \Phi_2}{\partial t^2}=\frac{1}{g^2}\frac{\partial \Phi_1}{\partial t}\bullet$$
$$\frac{\partial}{\partial z}\left[g\frac{\partial \Phi_1}{\partial z}+\frac{\partial^2 \Phi_1}{\partial t^2}\right]-\frac{\partial}{\partial t}(\nabla_3\Phi_1)^2, z=0 \quad (6)$$

The free-surface displacement at the first order, ς_1, is related to Φ_1 by

$$\varsigma_1=-\frac{1}{g}\left[\frac{\partial \Phi_1}{\partial t}\right]_{z=0} \quad (7)$$

The second-order correction, ς_2, is the sum of two parts,

$$\varsigma_2=\left[\frac{1}{g^2}\frac{\partial \Phi_1}{\partial t}\frac{\partial^2 \Phi_1}{\partial t \partial z}-\frac{1}{2g}(\nabla_3\Phi_1)^2\right]_{z=0}+\left[-\frac{1}{g}\frac{\partial \Phi_2}{\partial t}\right]_{z=0} \quad (8)$$

The first part can be immediately calculated from the first-order solution, while the second depends on the second-order potential Φ_2 which is to be found.

3. Correlation and Frequency Spectrum

We define the correlation function of the total free-surface height $\varsigma(x,y,t)$ by the following ensemble average

$$H(x,y,t)=\overline{\varsigma(x,y,t)\varsigma^*(x,y,t+\tau)} \quad (9)$$

where ς^* denotes the complex conjugate of ς. The corresponding frequency spectrum S is its Fourier transform,

$$S(x,y,\omega)=\frac{1}{2\pi}\int_{-\infty}^{\infty}H(x,y,\tau)e^{i\omega\tau}d\tau \quad (10)$$

In the sequel, the integration limits $(-\infty,\infty)$ will be omitted for brevity. Introducing the expansion (1), the total correlation function of the free surface comprises of quadratic products $(\varsigma_1,\varsigma_1)$ at order $O(\varepsilon^2)$, $(\varsigma_1,\varsigma_2)$ at $O(\varepsilon^3)$, and $(\varsigma_2,\varsigma_2)$, $(\varsigma_1,\varsigma_3)$ at order $O(\varepsilon^4)$. Since $\varsigma_1,\varsigma_2,\varsigma_3,...$ involve Fourier transforms with integrands proportional to A, AA, AAA ,... respectively, the right-hand side involves ensemble averages of even and odd products of A. Assuming A to be a Gaussian random variable, all odd products give zero averages, while all even products can be reduced to averages of quadratic products. It follows that nonlinear corrections begin at $O(\varepsilon^4)$,

$$H(\tau)=H_2(\tau)+H_4(\tau)+O(\varepsilon^6) \quad (11)$$

where

$$H_2(\tau)=\overline{\varsigma_1(t)\varsigma_1^*(t+\tau)},\qquad H_4=H_{22}+H_{13}+H_{31} \quad (12)$$

with

$$H_{22}(\tau)=\overline{\varsigma_2(t)\varsigma_2^*(t+\tau)},\quad H_{13}(\tau)=\overline{\varsigma_1(t)\varsigma_3^*(t+\tau)},\quad H_{31}(\tau)=\overline{\varsigma_3(t)\varsigma_1^*(t+\tau)}, \quad (13)$$

Note that $H_2=O(\varepsilon^2)$ and $H_4=O(\varepsilon^4)$ .The corresponding total frequency spectrum is

$$S=S_2+S_4+...=S_2+(S_{22}+S_{13}+S_{31})+... \quad (14)$$

where S_2 is the Fourier transform of H_2 as defined by (10). The nonlinear correction is represented by the three terms in the parenthesis, where S_{22},S_{13},S_{31} are respectively the Fourier transforms of H_{22},H_{13},H_{31}.

Let the free-surface displacement of the leading-order waves be

$$\varsigma_1^I(x,y,t)=\int_{-\infty}^{\infty}A(\omega)\exp(i\vec{k}\square^{-}-i\omega)d\omega \quad (15)$$

where $\omega^2=gk\tanh kh$. By the assumption of stationarity, it can be shown that

$$\overline{A(\omega_1)A^*(\omega_2)}=S_A(\omega_1)\delta(\omega_1-\omega_2) \quad (16)$$

where $S_A(\omega)$ is the spectrum of the first-order incident wave.

To account for diffraction by lateral boundaries of the coast and the harbor, and refraction by complex bathymetry, we express the total first-order displacement by

$$\varsigma_1=\int A(\omega)\Gamma_1(x,y,\omega)e^{i\omega t}d\omega \quad (17)$$

It is easy to show that the frequency response (transfer function) Γ_1 can be found from the linear scattering theory for monochromatic incident waves. Once Γ_1 is found by any of the existing methods, the leading-order response spectrum is

$$S_2(x,y,\omega)=S_A(\omega)\,|\,\Gamma_1(x,y,\omega)\,|^2 \quad (18)$$

In typical sea spectra such as JONSWAP and its extension to finite water depth (see Figure 1), S_A is