Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 127 (2015) 598 – 604

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Computational Heat and Mass Transfer-2015

Hydrodynamic Modeling of Moored Ship Motion in an Irregular Domain

Prashant Kumar[a]*, Kim Kwang Ik[b]

[a]National Institute of Technology, Department of Applied Sciences, Delhi
Sec-A7, Institutional Area, Narela, New Delhi-110040, India
[b]Department of Mathematics, Pohang University of Science and Technology,
Pohang-790784, South Korea.

Abstract

In this study, a hydrodynamic model for the analysis of moored ship motion is presented in a realistic harbor with highly irregular geometry. An accurate description of the harbor geometry, bathymetry and the associated wave's characteristics such as diffraction, refraction and partial reflection is required for the analysis of moored ship motion. Further, Fluid domain is divided into bounded, unbounded or open sea and ship region. In each region, wave field is determined by using Boundary Element Method (BEM) with the corner contribution and Chebyshev point discretization. Then, the hydrodynamic coefficient such as added mass and damping coefficients were determined based on the equation of motion with six degree of freedom, which represent the six different component of moored ship motion as surge, sway, heave, roll, pitch and yaw. The current numerical model is validated through previous well defined model based on moored ship motion. Moreover, current numerical scheme is implemented on realistic Pohang New Harbor (PNH), which is situated in Pohang city, South Korea to analyze the wave field in ship region under the various resonance frequencies for monochromatic incident waves.

Peer-review under responsibility of the organizing committee of ICCHMT – 2015

Keywords: Moored ship motion; Boundary Element Method (BEM); Hydrodynamics coefficient; Pohang New Harbour (PNH).

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: prashantkumar@nitdelhi.ac.in

Peer-review under responsibility of the organizing committee of ICCHMT – 2015
doi:10.1016/j.proeng.2015.11.350

1. Introduction

Harbours are designed to obstruct the incoming waves from the open sea and to protect moored ships and offshore structures. The high amplitude incident waves generated by seasonal typhoon are observed in the industrial PNH, which is hazardous to offshore structure, interior boundary of harbour and moored ship. The PNH is situated in southeast part of South Korea, which is designed to support the POSCO steel corporation. Moored ship in the harbour might experience the different external forces such as wind force, current force, and the hydrodynamics forces due to incident wave from various directions. A small portion of incident waves are radiated through entrance to the open sea and remaining portion is diffracted, refracted and partially reflected repeatedly by boundary of moored ships and the interior boundary of the harbour.

Many researchers have developed several numerical schemes to analyse the hydrodynamic response of moored ship in a real harbour. However, these approaches are model based which are useful to predict the wave field at moored ship in the harbour of arbitrary complex geometry. A numerical scheme was developed by Oortmessen [1] to analyse the moored ship in shallow water waves in a harbour. Sawaragi and Kubo [2] investigated Boundary Integral Equation Method (BIEM) using three dimensional (3D) Green's functions, which is applied on a rectangular floating body in a rectangular harbour. Takagi and Naito [3] independently developed a mild slope equation model applied to the 2-D geometry with the variation of bottom topography by using a Finite Element Method (FEM). Further, a combined method is formulated with the combination of 3-D BEM and 2-D FEM, which is applied on moored ship motion in a harbour [4, 5]. A hybrid Boussinesq panel method is utilized to predict the various modes of moored ship motion in restricted water depth [6, 7, 8]. Based on the field observation, a hybrid potential theory is investigated to predict the moored ship motion induced by tsunami waves [9, 10]. Recently Kwak and Pyun [11] used CGWAVE model to analyse the moored ship motion in PNH.

In this paper, we have designed a mathematical model for the hydrodynamics of moored ship motion, in which boundary corner contribution and Chebyshev point discretization is utilized. The main analysis consists of two parts. Firstly, the wave field for bounded and unbounded region are evaluated under the partial reflection boundary conditions [12] for different resonant frequencies waves with various directions. Further, applying the constant density assumption under the consideration of linearized kinematic and dynamic surface boundary conditions, Laplace equation is solved by using 3-D BEM to obtain the six different modes of moored ship motion in the ship region. Secondly, the present numerical simulation result is validated through the comparison with the previous well defined model given by Sawaragi and Kubo [2] and Takagi and Naito [3]. Then, the present numerical model is applied on realistic PNH domain under the resonance conditions for various monochromatic waves.

2. Model Formulation

The fluid domain is divided into three regions, i.e., bounded region (harbor), unbounded region (open sea) and the ship region. The bounded region Ω_b with uniform depth h_2 is surrounded by the harbor wall S_W including the harbor entrance E_1E_2. The unbounded region Ω_u with uniform depth h_1 is the open sea region, which includes the exterior coastal boundary (see Fig. 1). The ship region Ω_s with uniform depth h_3, which includes the moored ship S_M enclosed by semi-circular boundary S_0 with sea floor S_B. The lateral and front view of moored ship is shown with incident wave angle α onto the moored ship. The rectangular ship with length (L_S), width (B_S), height (H_S) and draft (D_S) located at the boundary of the harbor to analyze the moored ship motion (see Fig. 1).

2.1. Governing Equation

Firstly, we utilized Helmholtz equation in bounded and unbounded region to determine the wave induced oscillation in an arbitrary shaped harbour consider the corner contribution and Chebyshev Point discretization ([13]). Then, velocity potential is evaluated in the bounded and ship region. In ship region, the potential function is expressed in terms of diffraction and radiation potential as following

$$\phi^{(3)}(x,y,z,t) = \mathrm{Re}\left[\left\{\phi_0(x,y,z) + \sum_{j=1}^{6}\phi_j(x,y,z)\right\}e^{-i\omega t}\right], \quad (1)$$