Hydroelastic Analysis and Statistical Assessment of Flexible Offshore Platforms

HeonYong Kang* and Moo-Hyun Kim*
Ocean Engineering Program, Department of Civil Engineering, Texas A&M University
College Station, Texas, USA

Recently, various types of flexible offshore structures, such as floating offshore airports and bridges, multiple connected floating breakwaters, and wind/wave energy converters, have been proposed. When designing such large-scale flexural floating structures, a complete coupled hydroelastic theory, including the floating structures’ deformation and their interactions, needs to be developed; that is, a more complete diffraction/radiation/hydrostatic/inertia-analysis tool, including all the essential elastic modes, has to be used for more reliable dynamic analysis. Such a hydroelastic theory and the numerical tool have been developed in the frequency domain. The developed numerical analysis is applied to a barge-type floating elastic body with various bending stiffness after convergence tests against the number of high-order elements and elastic modes. Fully-coupled interactions among elastic motions, 6-DOF (degree of freedom) rigid-body motions, and diffracted and radiated waves are solved for a wide range of wave frequencies and the corresponding RAOs (response amplitude operators) are achieved. The elastic-mode RAOs are compared against those obtained from an independently developed time-domain program for verification purposes. Subsequently, distributions of shear forces and bending moments are achieved on the basis of the balance of inertia, restoring loadings, and hydrodynamic loadings. The stress resultants are also verified against the independently developed time-domain program and a plate theory-based calculation. The contributions of constituent components for the shear forces and bending moments are also compared. By using the frequency-domain results, how to estimate the statistical maximum shear force and bending moment along the sections of the barge in irregular waves is explained by two different approaches. In both dynamic and structural analyses, the resonance phenomena for elastic modes are investigated and discussed.

INTRODUCTION

The world’s growing economy and population demand larger-scale food production, extended harbors and transportation systems, and more mineral/energy extraction from the ocean. These demands require larger and more complicated ocean structures. An example is the MegaFloat (1000 × 60 (120) × 3 m), a close-to-prototype floating airport constructed in Tokyo Bay. The U.S. Navy also conducted a MOB (mobile offshore base) project, which includes the development of a naval offshore airport in the open sea by the connection of many identical floating units. This class of structures is known as very large floating structures (VLFS) because of its enormous size and displacement. Due to its large length-to-breadth/height ratio, the MegaFloat or MOB behaves as a flexible structure, which requires an analysis, called “hydroelasticity,” to account for fully-coupled interactions among 6-DOF motions, elastic motions, and waves. Other examples of future marine structures for which the hydroelasticity is important are large-scale, multi-unit-mounted FOWTs (floating offshore wind turbines) or WECs (wave-energy converters). Many of them are to be quite flexible and elastic.


In this study, the general wave-floater interaction solver, including elastic modes based on a 3D diffraction/radiation program (Newman, 1994), is extended to calculate local loads and the corresponding shear forces and bending moments. To get satisfactory accuracy in short waves, the 4th order B-spline with Galerkin method is used. By using the modal expansion method, elastic motions are applied in terms of modal matrices after diagonalization by orthogonality of mode shapes. A convergence test for the number of high-order elements and mode shapes is made with regard to full distribution of stress resultants. After obtaining fully-coupled dynamic solutions, including 6-DOF and elastic-mode contributions, shear force and bending moment are calculated from all the constituent-component loadings. A case study is conducted for an 80 × 10 × 5 m box barge with various flexural rigidities in head wave condition. Variations of shear forces and bending moments with wave frequencies are systematically investigated, and...