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3-D Calculation for Multiple Floating Bodies in Proximity Using Wave Interaction Theory

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With an increase in the number of floating bodies, the calculation for wave-body interactions becomes formidable with the direct panel method. In such a case, the wave interaction theory may be used. However, there is a mathematical limitation in applying the theory that each interacting body must be far enough apart from the other bodies. In practice, however, the wave interaction theory has been used successfully even for a case where the separation distance between the bodies is virtually zero. In this paper, numerical investigation is made of the practical applicability of the wave interaction theory by considering 4 identical box-shaped bodies as a practical example, and comparing computed results with correct ones obtained by the higher-order boundary element method (HOBEM). It is shown that the wave force in the horizontal direction can be obtained favorably by the interaction theory even if the separation distance between the bodies is very small, but that is not the case for the wave force in the vertical direction. This somewhat strange phenomenon is explained by cancellation of the surge forces from virtually contiguous vertical planes, although the pressure may not be correct on a region very close to adjacent bodies.

INTRODUCTION

The analyses of hydrodynamic interactions among multiple floating bodies have been of practical importance in the field of ocean engineering, such as offshore platforms supported by multiple columns and recently Very Large Floating Structures (VLFS), mainly studied in Japan, and Mobile Offshore Bases (MOB), mainly studied in the United States. When the number of bodies is not so large, direct numerical computations based on the panel method may be performed. However, as the number of bodies increases, this direct calculation method becomes formidable due to an extremely large number of unknowns and thus long computation time. In such a case, the wave interaction theory can be used. This theory is based on:

• expanding the velocity potential due to a single body with harmonic functions in the cylindrical coordinate system;

• using Graf's addition theorem for Bessel functions to transform to the local coordinates of the other bodies; and,

• solving the generalized diffraction problems for each of the bodies with the waves' effects scattered by the other bodies taken into account.

This interaction theory was first introduced to water-wave problems by Ohkusu (1974) and has been developed and extended by Kagemoto and Yue (1986), Linton and Evans (1990), and others. This wave interaction theory looks attractive when a large number of bodies exists. However, there is a mathematical limitation in applying this theory regarding the separation distance relative to the size of the bodies. Specifically, it is said that the bodies must be far enough apart so that the circles circumscribing the bodies do not overlap. In spite of this limitation, Murai et al. (1997) applied the wave interaction theory to the hydroelastic problems of VLFS in such a manner that the structure is divided into a large number of substructures, and hydrodynamic interactions among substructures are computed by the wave interaction theory, while the structural rigidity is taken into account in the motion equations of each substructure. In this calculation method, the separation distance between the nearest substructures is virtually zero, and thus the mathematical limitation in the wave interaction theory is obviously violated. However, Murai et al. (1997) claim that their calculation method works well, and in fact computed results of the elastic deformation of VLFS are in good agreement with measured ones. We should investigate further whether the wave interaction theory can be practically used even for cases which in theory violate the mathematical limitation. It may be the case that the numerical errors are not so large and practically negligible even for the case where applying the wave interaction theory is mathematically not correct.

This paper is a fundamental study of how far each of the multiple bodies must be separated (or contiguous) to ensure that the numerical results by the wave interaction theory can be used in practice. For a square arrangement of 4 identical box-shaped bodies floating in water of finite depth, numerical computations are performed for the wave diffraction problem by means of the wave interaction theory of Kagemoto and Yue (1986) and the higher-order boundary element method (HOBEM) developed by Kashiwagi (1995), which uses a 9-point quadratic representation on each panel for both the body shape and unknown velocity potential. Validity of the results by the wave interaction theory is discussed through a comparison with the results by HOBEM, which are confirmed to be accurate irrespective of the value of the separation distance between the bodies. It is shown that the integrated horizontal wave force becomes correct when the separation distance approaches zero due to the cancellation of the forces acting on the 2 contiguous vertical planes, while the vertical wave forces around some frequencies are different from correct values computed by HOBEM.

CALCULATION METHODS

Formulation

Since this paper is concerned with whether the wave interaction theory by Kagemoto and Yue (1986) can in practice be

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