

Time-Domain Analysis of Motion Responses of Adjacent Multiple Floating Bodies in Waves

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ABSTRACT

This study considers the motion responses of multiple adjacent floating bodies in waves. In order to find a solution, a three-dimensional Rankine panel method is adopted in the time domain. In order to obtain validation of the developed numerical method, the motions are estimated of two adjacent Series 60 hulls and a ship-barge model. The computational results are compared with other numerical and experimental analyses, and they showed a favorable concurrence. It was also discovered that the distance between ships affects the motion responses of multiple bodies.

KEY WORDS: Multiple-body problem; Rankine panel method; time-domain; ship motion problem.

INTRODUCTION

A multiple-body problem requires a solution to the cause of the motion and forces of adjacent multiple bodies in waves. Recently, since an LNG has been developed as an alternative energy resource, the relative motion between the LNG-FPSO and the LNG carriers became an important issue in the multiple-body problem. Related research is therefore currently being carried out.

Ohkusu (1974) first solved the multiple-body problem, while Oortmerssen (1979) applied the 3-D sink-source method. Kodan (1984) measured the motions of an adjacent barge and ship in waves. Currently, a strip theory has been applied to solve the multiple-body problem. As the computational capacity has evolved, 3-dimensional approaches have become popular and the wave green function (WGF), and the higher-order boundary element method (HOBEM) have been applied by Chen and Fang (2000) and Choi and Hong (2002). Kim (2003) applied a unified theory, and Kashiwagi et al. (2005) measured the mean drift forces on the Wigley and barge problem. Recently, Zhang (2007) applied the Rankine panel method (RPM) to the multiple-body problem. All of the numerical schemes, with the exception of the Rankine panel method, are limited to a linear problem, because they are based on frequency-domain solutions. An impulse response function (IRF), which is regarded as a time-domain approach, also uses

frequency-domain solutions. On the other hand, the Rankine panel method can be applied to nonlinear problems, such as a fully nonlinear free-surface problem or a body nonlinear problem, by considering the exact-wetted surface. The Rankine panel method is therefore a popular method currently being applied to single ship motion problems. The method was initiated by Dawson (1977) and Sclavounos and Nakos (1988) conducted a stability analysis for the Rankine panel method. Nakos (1990) developed it to a frequency-domain solver on an unsteady problem. Lin and Yue (1990) and Kring (1994) then developed it to a time-domain solver, and later extended it to nonlinear problems (Lin et al., 1994; Kring et al., 1996). However, there are few research cases in which the Rankine panel method is applied to the multiple-body problem.

This paper presents a mathematical background concerning a time-domain multiple-body problem by using the Rankine panel method. The method is applied to two adjacent Series 60 ($C_b=0.7$) problems and to a ship and barge problem, which was tested by Kodan (1984). By comparing the experimental data with various numerical results, characteristics of the multiple-body problem were observed. The results of the Rankine panel method as well as other methods are discussed in this paper.

MATHEMATICAL FORMULATION

Equation of Motion

In a multiple-body problem, the degree of freedom is determined by the number of multiple bodies. If there are two ships and each body is rigid, it has 12 degrees of freedom. Fig. 1 shows the definition of the coordinate system and notations. The motion of each body is defined in each local coordinate system. In this figure, β is the wave heading angle and D_L is the distance at the center position of Body-A and Body-B. Eq. 1 is the equation of motion on two body problems.

$$\begin{aligned} [M]_A \{\ddot{\xi}_i\} + [C]_A \{\dot{\xi}_i\} &= \{F_{F.K.} + F_{H.D.}\}_A & i = 1, 2, \dots, 6 \\ [M]_B \{\ddot{\xi}_j\} + [C]_B \{\dot{\xi}_j\} &= \{F_{F.K.} + F_{H.D.}\}_B & j = 7, 8, \dots, 12 \end{aligned} \quad (1)$$