ABSTRACT

When multiple floating bodies are situated closely, hydrodynamic interactions among bodies are expected to be large and complex. These hydrodynamic interactions should be taken into account not only in hydrodynamic forces of first order in the incident-wave amplitude but also in time-averaged steady forces of second order which are called the wave drift force. In this paper, it is shown that the wave drift force on a floating body can be reduced to almost zero at a specific wavenumber, by placing extra supporting columns in a way of surrounding the floating body and utilizing the ‘cloaking’ phenomenon. Furthermore to reduce the wave drift force for a wider range of wave frequencies, we propose to control the parameters of outer surrounding columns such as draft and distance from the inner floating body at each frequency. These parameters of surrounding columns are optimized in this paper by a genetic algorithm so as to minimize the total scattered-wave energy. For numerical computations with high accuracy, the wave interaction theory combined with higher-order boundary-element method is adopted and the integral with respect to the azimuth angle in the formula of wave drift force is analytically performed.

KEY WORDS: Cloaking; wave drift force; scattered-wave energy; far-field method; higher-order boundary element method; genetic algorithm.

INTRODUCTION

In recent years, offshore structures tend to become complicated, consisting of a large number of element bodies, or multiple floating bodies exist in proximity such as side-by-side arrangement of LNG-FPSO. In such situations, hydrodynamic interactions among floating bodies are expected to be large and complex, changing its magnitude of interaction depending on the frequency of incident wave. As a result, offshore structures may be damaged due to severe hydrodynamic interactions. Therefore, these interactions need to be computed accurately not only in hydrodynamic forces and resulting wave-induced motions of first order in the incident-wave amplitude but also in time-averaged steady forces of second order which are called the wave drift force. On the other hand, there is a possibility that the wave drift force can be reduced by controlling hydrodynamic interactions and eventually by realizing no radial outgoing waves outside the structures.

Recently, Newman (2013) has considered the possibility of ‘cloaking’ a circular cylinder which is of finite draft and fixed on the free surface in a fluid of infinite depth, by surrounding it with outer bodies. Cloaking refers to the condition that there is no wave scattering in the form of radial outgoing waves in the diffraction problem. Since the wave drift force can be calculated by the amplitude of scattered waves, the wave drift force may be zero if there are no scattered waves.

In this paper, following Newman’s idea, we attempt to reduce the wave drift force by utilizing positively the cloaking phenomenon to be observed by placing columns which surround the inner floating body under consideration, as shown in Fig. 1. Since the cloaking phenomenon is associated with wave trapping between the inner and surrounding floating bodies and it is sensitive to the change in wave frequency, we need to use an accurate and reliable calculation method for computing the wave drift force on each element of the whole structure. Newman used WAMIT which is a 3D constant-panel method. In the present study, to keep higher accuracy in computed results, a higher-order boundary element method (HOBEM) developed in Kashiwagi (1995) is used for com-

Fig. 1 Perspective view of the entire structure with $N = 8$ supporting columns