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Simulation of Heaving Body under Free Surface by Vortex Methods

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ABSTRACT

To utilize floating structure under heavy environmental condition in sea safely, motions of the floating structure and the mooring forces have to be reduced. To decrease these motions and mooring forces, fins attached structure has been proposed. In this paper, as a first step of the study, two vortex methods, the Random-Walk method and the Core-Spreading method, are applied to vertical oscillating plate under free surface. Hydrodynamic forces on the plate are calculated and compared with experimental results.

KEY WORDS: Vortex method; Random-Walk method; Core-Spreading method; Heaving plate; Hydrodynamic force; Complex variable boundary element method; Dual-variable equivalence method

INTRODUCTION

It has been required that the ocean space is effectively used in Japan surrounded by the sea and various floating structures for development of ocean resources or oceanographic survey, etc. have been proposed. In recent years, the floating structures for utilizing ocean energy such as offshore wind farms or ocean thermal energy conversions are required because of depletion of fossil fuels, global warming and the accident in the nuclear power plant by the eastern Japan earthquake. Moreover, the floating structure seems to be useful as disaster prevention bases or shelters, because the damage of the floating structures in the tsunamis caused by the eastern Japan earthquake were relatively small. Therefore, various types of floating structure will be required in future.

To utilize floating structure in safely economically under severe wind and wave conditions around our country, motions of the floating body and mooring forces acting on the body have to be reduced. To decrease these motions and mooring forces, fins attached structure has been proposed (Fig. 1). The attached fin seems to dissipate the energy of the motion as viscous damping and reduce the mooring forces due to so-called “wave devouring propulsion” effect. To put this method to practical use, the calculation method to design optimum shape and arrangement of the fin has to be developed. The calculation method is required to be applicable to arbitrary body shape under free surface and simulate viscous effects such as generation and diffusion of vortex from the fins.

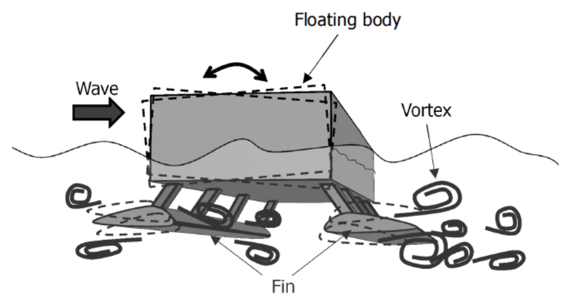

Fig. 1 Floating body with fin

The vortex method seems to be useful for this purpose. The vortex method simulates flows by representing vorticity distributions with discrete vortex elements and calculating trajectories of these elements in a Lagrangian form. This method, which doesn’t need spatial grid, can be applied to arbitrary body shape and track the movement of the computational boundary.

It seems that there has been no research applying the vortex method to the free surface flow except for the series of studies by Yeung et al. (e.g. Yeung and Cermelli 1998, Yeung 2002). They simulated two-dimensional rolling motion of the floating body with the small sized fin by using Random-Walk method (Chorin 1973) for vorticity diffusion and compared the calculation results with the experimental results. However, the accuracy of their calculation results is not enough for the purpose of our study. In order to examine the optimum shape and arrangement of the fin to reduce the motions and the mooring forces of the floating body, hydrodynamic forces acting on the fin and fluid field around the fin have to be simulated with high accuracy.

Recently, the vortex method remarkably progresses and some books which describe the whole of vortex methods have been published (Cotte and Koumoutsakos (2004) ; Ying and Zhang (1997)). Especially, a lot of viscous diffusion model, such as stochastic Random-Walk method and deterministic Resampling method, Particle Strength Exchange method, Redistribution method and Core-Spreading method etc., have been proposed. In recent years, the Core-Spreading method proposed by Leonard (1980) is more advanced and the high-resolution models for vortex generation and diffusion near the body have been developed (Ota and Kamemoto 2004; Imamura et al. 2005).

The purpose of this study is to develop the numerical method with