International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 18, No. 2, June 2008, pp. 106–111

Performance Prediction of Surface-Piercing Bodies in Numerical Towing Tank

Sakir Bal
Faculty of Naval Architecture and Ocean Engineering, Istanbul Technical University
Maslak-Sariyer, Istanbul, Turkey

In this paper, the steady flow characteristics around 3-dimensional cavitating or noncavitating bodies (such as hydrofoils, struts and ships) inside a numerical towing tank (NTT) are investigated by an iterative boundary element method (IBEM). The iterative nonlinear method is based on Green's theorem, which is applied to the surfaces of the cavitating or noncavitating surface-piercing body, to the walls of the NTT and to the free surface. The integral equation based on Green's theorem is divided into 5 parts: the surface-piercing body; the free surface; the NTT's right sidewall, left sidewall and bottom surface. Those 5 problems are solved separately, with the effects they have on one another being accounted for in an iterative manner. The cavitating or noncavitating 3-D surface-piercing body is modeled with constant strength dipole and constant strength source panels, distributed over the body surface including the cavity surface. The free-surface part and the NTT's sides and bottom surface are also modeled with constant strength dipole and source panels. The method is first applied to a rectangular surface-piercing hydrofoil and validated with experimental measurements. The method is then applied to a cavitating rectangular hydrofoil, and the effects of the reflected waves from the NTT's sidewalls on cavity characteristics and Kelvin wave pattern are discussed.

INTRODUCTION

This paper describes an iterative boundary element method (IBEM) for the prediction of characteristics of steady flow around 3-dimensional cavitating or noncavitating surface-piercing bodies—such as ships, struts and hydrofoils—and inside a numerical towing tank (NTT); some numerical results are given.

Kinnas and Fine (1993) modeled the flow around 3-D cavitating hydrofoils in an unbounded fluid domain. A nonlinear theory was applied by employing a low-order potential-based boundary element method. Kinnas, Hong and Lee (2003) later extended this method to predict face cavitation and search for cavity detachment on 3-D hydrofoils. Hsin and Chou (1998) applied an iterative panel method for surface-piercing bodies (hydrofoils or ships) without cavitation. Kim (1992) also solved the submerged high-speed hydrofoil problem without the effect of cavitation. Mainar, Newman and Xu (1990) used the Havelock type of singularities to treat the flow around yawed surface-piercing plates. On the other hand, Kinnas, Lee and Mueller (1998) calculated the tunnel wall effects on cavitating hydrofoils without free-surface effect by iterative methods based on Green's theorem. The tunnel problem and the hydrofoil (or marine propeller) problem were solved separately, with their effects on each other being accounted for in an iterative method. The hydrofoil (or marine propeller) problem was solved in the context of nonlinear cavity theory by employing a low-order potential-based boundary element method (Kinnas and Fine, 1993). Also used were normal dipole and source distribution, on the cavity surface, the hydrofoil surface and the tunnel walls. The tunnel problem was solved by applying the zero normal velocity condition. An IBEM was described in Bal, Kinnas and Lee (2001) for both 2-D and 3-D submerged cavitating hydrofoils under linearized free-surface condition. The integral equation obtained by applying Green's theorem on the surfaces of the problem was divided into the cavitating hydrofoil part and the free-surface part. The cavitating hydrofoil influence on the free surface, and the latter's influence on the cavitating hydrofoil, were considered via potential. Some convergence tests were carried out, and Bal and Kinnas (2002) gave extensive numerical results of this IBEM. The effects of an NTT's sidewalls and bottom surface on both 2-D and 3-D submerged cavitating hydrofoils were also included into the calculations in Bal and Kinnas (2003); Bal gave some extensive results of the method (2006). In this paper, however, the iterative method originally developed in Bal and Kinnas (2003) and Bal (2006) is modified and extended to apply to the surface-piercing bodies (with or without cavitation) inside an NTT, and some numerical results of the method are given. The extended version of this method applied to cavitating or noncavitating surface-piercing hydrofoils was given in Bal (2008) without the effect of NTT. On the other hand, some extended results of this corresponding method with the effect of NTT can be found in Bal (2007).

In the method applied here, the integral equation based on Green's theorem is divided into 5 parts:

- the cavitating (or noncavitating) body part
- the free-surface part
- the NTT's right sidewall
- the NTT's left sidewall
- the NTT's bottom surface

These 5 problems are solved separately, with their effects on each other being accounted for in an iterative manner. It can be said that these 5 problems communicate (talk to each other, as it were) via potential. A cavitating (or noncavitating) body part in 3-D is modeled with constant strength dipole and source panels. The free-surface part, the NTT's left and right sidewalls and bottom surface are also modeled with constant strength dipole and source panels. Source strengths on the free surface are proportional to the derivative of the perturbation potential with respect to the vertical (z) axis. They are expressed by using the linearized free-surface condition, in terms of the second derivative of the perturbation potential with respect to the horizontal (x) axis as in Bal, Kinnas and Lee (2001). The corresponding 2nd-order derivative on the

Received October 15, 2007; revised manuscript received by the editors January 15, 2008. The original version (prior to the final revised manuscript) was presented at the 17th International Offshore and Polar Engineering Conference (ISOPE-2007), Lisbon, July 1–6, 2007.
KEY WORDS: Cavitating hydrofoils, struts, ship wave pattern, numerical towing tank, free surface, wave drag, boundary element method.