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Surface Piercing Bodies in a Numerical Towing Tank

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ABSTRACT

In this paper the steady cavitating or non-cavitating flows around three-dimensional bodies (such as hydrofoils, struts, ships etc) inside a numerical towing tank (NTT) are addressed by an iterative boundary element method (IBEM). The iterative nonlinear method is based on the Green's theorem, which is applied to the surfaces of the cavitating or non-cavitating surface piercing body, to the the walls of NTT and to the free surface. The integral equation based on Green's theorem is divided into five parts: (i) The surface piercing body part, (ii) The free surface part, (iii) The right side wall of tank, (iv) The left side wall of tank and (v) The bottom wall of tank. These five problems are solved separately, with the effects of one on the others being accounted for in an iterative manner. The cavitating or non-cavitating three-dimensional 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 side and the bottom walls of NTT are also modeled with constant strength dipole and source panels. All these parts of the problem are solved separately, with the effects of one on the others being accounted for in an iterative manner. For the validation of the method it is first applied to a Wigley hull Then, the method is applied to a cavitating rectangular hydrofoil and the effects of the reflected waves from walls of NTT on cavity characteristics are discussed.

KEY WORDS: Cavitating Hydrofoils; Struts; Numerical Towing Tank; Iterative Boundary Element Method; Free Surface, Wave Drag.

INTRODUCTION

This paper addresses the steady flow characteristics around three-dimensional cavitating or non-cavitating surface piercing bodies such as; ships, struts, hydrofoils, inside a numerical towing tank (NTT) by an iterative boundary element method (IBEM) and some numerical results are given.

The flow around three-dimensional cavitating hydrofoils has been modeled in an unbounded fluid domain in (Kinnas and Fine, 1991) and (Kinnas and Fine, 1993). A nonlinear theory was applied by employing a low-order potential based boundary element method. Their method was later extended to predict face cavitation and search for cavity detachment on three-dimensional hydrofoils and propellers (Kinnas, 1998) and (Kinnas, Hong and Lee, 2003). A localized finite element method with nonlinear free surface condition was described for two-dimensional hydrofoils in (Bai and Han, 1994). An iterative panel method has been applied for surface piercing bodies (hydrofoils or ships) without cavitation in (Hsin and Chou, 1998). (Kim, 1992) and (Ragab, 1998) also solved the submerged high-speed hydrofoil problem without cavitation. (Mainar, Newman and Xu, 1990) used Havelock type of singularities to treat the flow around yawed surface piercing plates. On the other hand, the tunnel wall effects on cavitating hydrofoils without free surface effect have been calculated by iterative methods based on Green's theorem in (Kinnas, Lee and Mueller, 1998) and (Choi and Kinnas, 1998). The tunnel problem and the hydrofoil (or propeller) problem were solved separately, with the effects of one on the other being accounted for in an iterative method. The hydrofoil (or 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) and (Kinnas, 1998). Normal dipole and source distribution both on the cavity surface and on the hydrofoil surface were used as well as on the walls of tunnel. The tunnel problem was solved by applying the zero normal velocity condition. An IBEM was described for both two-dimensional and three-dimensional submerged cavitating hydrofoils under linearized free surface condition in (Bal and Kinnas, 2000) and (Bal, Kinnas and Lee, 2001). The integral equation obtained by applying Green's theorem on the surfaces of the problem was divided into two parts; the cavitating hydrofoil part and the free surface part. The cavitating hydrofoil influence on the free surface and vice versa (the free surface influence on the cavitating hydrofoil) was considered via potential. Some convergence tests carried out and extensive numerical results of this IBEM were given in (Bal and Kinnas, 2002). Second-order free surface effect on the cavitation characteristics of the hydrofoil was discussed in detail by the technique of small perturbation expansion both for the potential and for the wave elevation in (Bal, 2001). The effects of walls (side and bottom walls) of a numerical wave tank on both two-dimensional and three-dimensional submerged cavitating hydrofoils were also included into the calculations in (Bal and Kinnas, 2003) and some extensive results of the method were given in (Bal, 2006). Some design figures of swept