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MATHEMATICAL APPROACH TO INVESTIGATE THE BEHAVIOUR OF THE PRINCIPAL PARAMETERS IN AXISYMMETRIC SUPERCAVITATING FLOWS, USING BOUNDARY ELEMENT METHOD

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ABSTRACT

In this paper, a direct boundary element method (DBEM) is formulated numerically for the problems of the unbounded potential flows past supercavitating bodies of revolution (cones and also disks which are special case of cones with tip vertex angle of 180 degree) at zero degree angle of attack. In the analysis of potential flows past supercavitating cones and disks, a cavity closure model must be employed in order to make the mathematical formulation close and the solution unique. In the present study, we employ Riabouchinsky closure model. Since the location of the cavity surface is unknown at prior, an iterative scheme is used. Where, for the first stage, an arbitrary cavity surface is assumed. The flow field is then solved and by an iterative process, the location of the cavity surface is corrected. Upon convergence, the exact boundary conditions are satisfied on the body-cavity boundary. For this work, powerful software, based on CFD code, is developed in CAE center of IUST. The predictions of the software are compared with those generated by analytical solution and with the experimental data. The predictions of software for supercavitating cones and disks are seen to be excellent. Using the obtained data from software, we investigate the mathematical behavior of axisymmetric supercavitating flow parameters including drag coefficients of supercavitating cones and disks, cavitation number and maximum cavity width for a wide range of cone and disk diameters, cone tip angles and cavity lengths. The main objective of this study is to propose appropriate mathematical functions describing the behavior of these parameters. As a result, among all available functions such as linear, polynomial, logarithmic, power and exponential, only power functions can describe the behavior of mentioned parameters, very well.

Keywords : Supercavitation, Axisymmetric, Boundary element method.

1. INTRODUCTION

Supercavitation is a revolutionary means to achieve drag reduction up to 90% on an underwater body [1]. This level of drag reduction will have dramatic effects on the operation of naval forces. The high level of drag reduction is achieved by enveloping the body within a gaseous cavity. Only small area at the nose (cavitator) remains in contact with the liquid.

The study of axisymmetric supercavitating flow problems has always been of great interest, since they are in general more applicable to reality than 2-dimensional models. Of the early work on infinite-length axisymmetric supercavitating flow, we note Reichardt [2], who experimentally studied the axisymmetric supercavitating flows, and Garabedian [3], who developed an analytical method for calculating cavity shapes, though the accuracy of the method he presented is limited. Following the work on axisymmetric flow by Reichardt [2] and Garabedian [3], attention was paid to finite-length cavities springing from bodies of revolution by a number of authors, such as Cuthbert and Street [4], Brennen [5], Chou [6], Aitchison [7], Hase [8] and Varghese, Uhlman and Kirschner [9]. These authors used a variety of techniques for modeling the supercavitating flows including finite difference, finite element, boundary integral and interior source methods.

The most useful information from a solution of a supercavitating flow problem is the spatial location of the free surface (cavity surface) and knowledge of velocities and/or pressures along the boundaries. This realization leads one to feel that domain-type techniques (such as FDM and FEM) are computationally inefficient and that the problem is ideally suited to a boundary element method (BEM) solution [10].

The boundary element method is based on the descritization of an integral equation that, mathematically, is equal to the governing partial differential equation of the problem. The one of the main advantages of the boundary element method is that in which, instead of the whole domain, we generate the mesh only on the boundaries of the domain and so, the number of the

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