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ASSESSMENT OF A CENTRAL DIFFERENCE FINITE VOLUME SCHEME FOR MODELING OF CAVITATING FLOWS USING PRECONDITIONED MULTIPHASE EULER EQUATIONS*

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Abstract: A numerical treatment for the prediction of cavitating flows is presented and assessed. The algorithm uses the preconditioned multiphase Euler equations with appropriate mass transfer terms. A central difference finite volume scheme with suitable dissipation terms to account for density jumps across the cavity interface is shown to yield an effective method for solving the multiphase Euler equations. The Euler equations are utilized herein for the cavitation modeling, because some certain characteristics of cavitating flows can be obtained using the solution of this system of equations with relative low computational effort. In addition, the Euler equations are appropriate for the assessment of the numerical method used, because of the sensitivity of the solution to the numerical instabilities. For this reason, a sensitivity study is conducted to evaluate the effects of various parameters, such as numerical dissipation coefficients and grid size, on the accuracy and performance of the solution. The computations are performed for steady cavitating flows around the NACA 0012 and NACA 66 (MOD) hydrofoils and also an axisymmetric hemispherical fore-body under different conditions and the results are compared with the available numerical and experimental data. The solution procedure presented is shown to be accurate and efficient for predicting steady sheet- and super-cavitation for 2D/axisymmetric geometries.

Key words: cavitating flows, preconditioned multiphase Euler equations, interface capturing method, central difference FVM

Introduction

The inception of cavitation occurs due to the drop in pressure of the flow below the vapor pressure of the liquid. The phenomenon is often encountered in a wide variety of hydraulic machinery and liquid handling devices. Ship propellers, hydraulic turbine and pumps, nozzles and hydrofoils are some examples subject to cavitation. The cavitation phenomenon has been the subject of intensive research because of its effects on performance, undesirable features of cavitation are structural failure, vibration, noise and loss of power. On the other hand, cavitation is sometimes found useful as its applications in ultrasonic cleaning, enhancement of chemical reactions, biomedical treatments and viscous drag reduction on high speed underwater bodies surrounded fully or partially with a natural or gas-ventilated cavity[1,2]. Numerical simulation of cavitating flows is a complicated task, since one has to deal with localized large variations of density which are present within a predominantly incompressible liquid medium, interactions between phases, turbulence, irregularly shaped interfaces and the stiffness in the numerical model. Because of these complexities there has not been a single sophisticated mathematical model that can involve all these factors.

Numerical attempts at the simulation of cavitating flows can be classified broadly as two categories: namely interface tracking and interface capturing procedures. Interface tracking methods benefit from the assumption of taking the cavitating region at constant pressure equal to the local vapor pressure. Thus, the liquid/vapor interface is treated as a part of the boundary and the computations are conducted for liquid phase only. Computationally, the cavity shape is updated with an iterative procedure to match the cavity interface to a constant pressure boundary. In addition, a wake closure model must be employed in the interface tracking approach to approximate the two-phase behavior in the wake region at the end of the cavita-

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