

ACCOUNT OF COMPRESSIBILITY EFFECTS WITHIN PRESSURE-BASED EULER-EULER APPROACHES TO CAVITATING FLOW SIMULATIONS

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Numerical modeling of cavitation can be classified into three main categories, i.e. barotropic equation of state, Euler-Euler or Euler-Lagrange. These approaches are based upon two-phase flow models composed of a vapor and a liquid phase. A widely used Euler-Euler approach adopted in the present study considers a two-phase flow as the flow of a liquid and vapour mixture, where the vapour fraction is defined by a transport equation. Several existing Euler-Euler models differ mainly in the definition of the source term in this equation responsible for the phase transfer.

Within the numerical models both phases may be considered as compressible or incompressible. The incompressible approach assumes isothermal flow and constant densities for vapor and water, whereas compressible approach usually consider vapor as perfect gas and employs Tait's or similar equation of state for water [3]. The major feature of the latter approach is that it allows to simulate pressure wave propagation after the vapor collapse which might be necessary e.g. for erosion risk estimation. At the same time modeling low Mach number compressibility is more complex numerically and besides very small time steps are required to capture shock effects [1].

In the present work a standard pressure-based SIMPLE algorithm is extended to account for density variations which occur due to changes in vapor volume fraction computed by an Euler-Euler cavitation model and due to phases compressibility. The compressible pressure-correction scheme is implemented along a route outlined in [2]. Since collocated variable arrangement is used in the numerical procedure, an important issue becomes interpolation routine to avoid pressure oscillations. Several approaches analyzed in the current work include the traditional for pressure-based solvers Rhie-Chow interpolation [2] and AUSM family methods [4] widely used for density-based methods including those with low Mach number corrections.

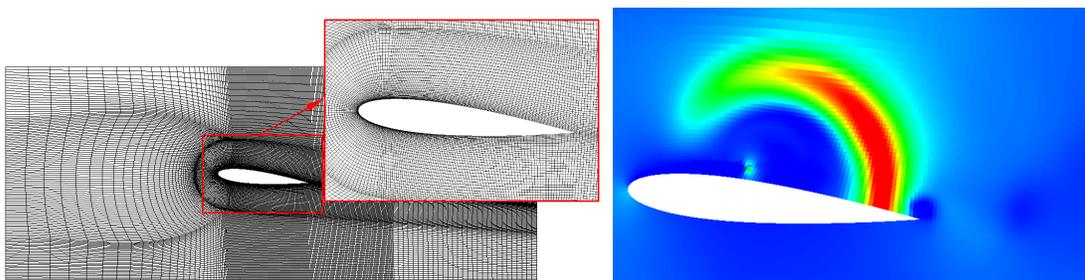


Figure 1: Cavitating flow over NACA0015 hydrofoil. Computational domain and grid overview (left), Shock wave propagation after vapor cavity collapse (right)

The developed algorithm has been validated for two “classical” compressible flow test cases such as compressible flow through a converging-diverging nozzle and flow over a bump in a channel. Compressibility aspects in conjunction with computational modelling of cavitating flows have been studied for flow over NACA66 hydrofoil at $Re=2 \cdot 10^6$ and 4° angle of attack (stationary test case) and NACA0015 hydrofoil at 6° of attack, chord Reynolds number of $1.56 \cdot 10^6$ and cavitation number $\sigma = 1.0$ (unsteady test case).

The obtained results demonstrate that the suggested algorithm allows to extend capabilities of the existing Euler-Euler cavitation models for shock waves prediction. Violent vapor cavity collapses resulting in high pressure peaks due to the liquid inertia (up to hundreds bars) and creation of shock waves can now be simulated with these models (see Figure 1). The remained drawbacks are well-known result dependence on model coefficients and requirement of very small simulation time steps. The future work suggests account of compressibility for Euler-Lagrange approach and application of the developed methods for erosion analysis.

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