Evaluation of Criteria for Adaptive Mesh Refinement in the Numerical Prediction of Hydrofoil Cavitation

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ABSTRACT

In the field of Marine Engineering, cavitation is relevant for the design of propellers. Propeller cavitation affects the energy efficiency of the propulsive system and can lead to cavitation nuisances. For the numerical prediction of unsteady cavitation, viscous flow solvers can be used. However, viscous flow simulations are costly, leading to the usual trade-off between computational cost and desired accuracy. One method to achieve high spatial resolution while keeping an acceptable cost is to employ an Adaptive Mesh Refinement (AMR) algorithm.

In this study, criteria for Adaptive Mesh Refinement to improve the prediction of transient cavitation are evaluated. The test case consists of a NACA0015 hydrofoil confined in a cavitation tunnel. The partial cavitation regime is considered, characterized by cyclic cloud shedding. The model relies on the unsteady RANS equations, with a Volume-of-Fluid approach for the multi-phase flow. The viscous flow solver ReFRESCO is used. Three criteria are tested for the adaptive mesh refinement: the first criterion is based on the non-dimensional value of the Q-factor, which was used by Lloyd et al. [1] for tip vortex cavitation; the second criterion is the jump estimator of the vapor volume fraction, presented by Eskilsson and Bensow [2]. A third option is tested, with a combination of the two above criteria. The initial mesh for all cases is a block-structured mesh, referred to as the *base mesh*. The results are validated against the experiment of Van Rijsbergen et al. [3]. Furthermore, a series of user-refined grids are produced, which are obtained by a geometrically-similar refinement of the structured *base* mesh. The results with manual refinement are compared with the results using ARM, to judge whether the AMR method is capable to refine the mesh in the regions of interest.

The first conclusion from this study regards the criteria for adaptive refinement; without explicit limitation of the locations where AMR is active, the Q-criterion results in a significant refinement in the wake of the foil, away from the region of interest; contrarily, the jump criterion for the vapor fraction leads to refinement only at the cavity interface. The combination of the two criteria provides the most satisfactory results: automatic refinement occurs not only within the attached sheet cavity, but also for the spanwise, cavitating vortices which are formed at the closure region.

A second conclusion concerns the trade off between cost and accuracy; with adaptive refinement the small-scale cavitating flow structures are captured with increased accuracy in comparison to the *base* mesh. To obtain the same level of details with a geometrically similar mesh, about 5 times as many cells are required, with the consequent rise in computational effort.

REFERENCES

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