Improved accuracy in cavitating flows using adaptive grid refinement

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ABSTRACT

The high lift required to raise foiling vessels above water is generated by increasing the flow velocity, thus decreasing the static pressure. If the saturation point is reached, cavitation begins to appear with the formation of vapor. Depending on the pressure drop, cyclic detachments of the vapor cavities from the surface can be observed. This phenomenon is referred to as shedding and is critical to the performance of a hydrofoil on fast vessels. Characterizing these cavitation dynamics is essential for the design, but modeling this highly turbulent, dynamic, and unstable two-phase flow is a challenge.

On top of the complexity of the non-cavitating flow, there is the need to properly capture low pressure regions and vapor cavities. This typically requires a very fine mesh with small cells in a large volume to make sure the discretization is high enough to capture vapor cavities during the entire cycle. Additionally, the use of computationally heavy models such as (I)(D)DES and LES is increasingly common in the literature to study complex cavitation cases.

Present work studies the use of Adaptive Grid Refinement (AGR) in Fine™ Marine on RANS simulations, to reduce the computational cost while increasing the precision. The automatic high-frequency mesh adaptation ensures an optimum number of cells at any given time, with the right refinement at any given location. It is achieved by using an interface-capturing criterion (between water and vapor) combined with the Hessians of both pressure and velocity. The previously successful application of this method on steady-state cases like ship resistance [1] and on the unsteadiness present in foil ventilation [2] paved the way for the application to cavitation. To validate the quality of the results, simulations have been performed on the well-known Delft Twist 11 test case and compared with two campaigns of tunnel testing carried out by Bouziad [3] and Foeth [4], as well as computational results from literature.

Excellent agreement is obtained with the dynamics observed in experiments, with a precise description of the cavity breaking, as well as the capturing of the smallest vapor structures. Comparison to surface pressure probes demonstrated a gain in accuracy compared to previous RANS simulations obtained by Vaz et al. [5]. The predicted lift is still lower than LES predictions, but the difference has been reduced from 8 to 6 percent for every configuration, including low sensitivity criterion settings. The obtained results prove that adaptive grid refinement can greatly improve the accuracy of RANS simulations, reducing the gap with expensive scale resolving methods for violent cavitation cases that are relevant in industry today.

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