Simulation of cavitation erosion by a coupled CFD-FEM approach.

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Abstract: This research is devoted to understanding the physical mechanism of cavitation erosion in liquid flows on the fundamental scale of cavitation bubble collapse. Cavitation bubbles forms in a liquid when the pressure of the liquid decreases locally below the saturated vapor pressure. The bubbles grow due to low ambient pressure and rapidly collapses when the surrounding liquid pressure increases. As a consequence of collapsing bubbles near solid walls, high pressure impact loads are generated. The primary bubble collapse is accompanied by the emission of shock waves and therefore, the fluid compressibility has to be considered. The pressure loads from primary bubble collapse and shock waves causes plastic deformation and eventually, mass loss in the solid. These pressure loads believed to be responsible for the erosive damages on solid surfaces, are observed in applications like liquid fuel injection, hydrodynamic power generation and marine propulsion. On the other hand, the pressure loads from collapsing bubbles are useful for applications like shock wave lithotripsy, drug delivery and cleaning surfaces. Our numerical approach begins with the development of a compressible solver capable of resolving the cavitation bubbles in the finite-volume code YALES2 employing a simplified homogenous mixture model. In cavitation erosion, the solid wall deforms under the influence of pressure loads from collapsing bubbles. Therefore, the solver is extended to Arbitrary Lagrangian-Eulerian formulation to equip with moving mesh capabilities in order to perform fluid structure interaction simulation. The material response is resolved with the finite element code Cast3M, which allowed us to investigate one-way and two-way coupled fluid-structure interaction simulations between the fluid and solid domains. In one-way coupling, no feedback of solid wall deformation on the fluid is considered whereas in two-way coupling, the feedback of solid wall deformation is considered in the fluid domain. In the end, we draw comparisons between 2D and 3D vapor bubble collapse dynamics and compare them with experimental observations. We estimate the pressure loads on the solid wall from collapsing bubbles and discuss the dynamical events responsible for surface damage. The response of different materials to bubbles collapsing at different distances from the solid wall is also discussed. Finally, we present results from two-way coupled fluid-structure interaction simulations where the damping of pressure loads by different materials is analysed.