Simulation of Elastic or Elastic-Plastic Solids Interacting with Two-Phase Flows for the Numerical Investigation of the Mechanism of Cavitation Damaging

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ABSTRACT

As a model problem to investigate the mechanism of cavitation damaging the collapse of a single gas bubble collapsing near to an elastic or an elastic-plastic solid wall is simulated numerically. This transient three-phase system is modelled by the compressible Euler equations completed by a stiffened gas law for both fluids, where the liquid and the gas phase are distinguished by a level set approach, and the elasto-plasto-dynamical equations for a linear-elastic-linear-plastic solid. The problem is characterized by two interfaces along which the jump conditions for contact discontinuities provide the transition conditions: the bubble wall forms a transiently deforming liquid-gas interface whereas an additional change of the system of governing equations features the coupling between liquid and the adjacent structure.

The balance laws for the two fluids and for the solid are discretized by adaptive finite volume schemes, whereas the implemented level set formulation for the tracking of the bubble wall is combined with the ghost fluid approach following for example Fedkiw/Osher, Wang/Liu/Khoo, Farhat/Rallu/Shankaran to stabilize the method at the liquid-gas interface.

Von Mises yield criterion is used to switch the slope of the stress—strain relations between Young's modulus and the plastic behavior characterizing modulus of rigidity for the structure according to Neubers method.

A weak coupling strategy connects the alternating calculations of the fluid solver and the solid solver using transient boundary conditions that are updated by the other solver. The inter-solver communication is realized by a free library for shared memory segments within the main memory of the computer accessible by both codes.

First numerical results show significant effects of the dynamical processes inside the solid on the bubble collapse and the wave phenomena in the fluid. The simulations show shock waves emitted from the collapsing bubble and correlated stress waves inside the structure which exceed the yield strength of structural steel within an almost spherically shaped region with its center on the symmetry axis at the solid surface. Such phenomena might be an explanation for cavitation damaging. The transition from pure elastic behavior of the solid to plastic effects causes additional wave phenomena.

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