A SPECTRAL-ELEMENT METHOD FOR MODELING CAVITATION IN TRANSIENT FLUID-STRUCTURE INTERACTION

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In an underwater-shock environment, cavitation, *i.e.*, boiling, occurs as a result of reflection of the shock wave from the free surface and/or wetted structure that causes the pressure in the water to fall below its vapor pressure. If the explosion is sufficiently distant from the structure, the motion of the fluid surrounding the structure may be assumed small, which allows linearization of the governing fluid equations. Felippa and DeRuntz [1] developed the cavitating acoustic finite element (CAFE) method for modeling this phenomenon. While their approach is robust, it is too computationally expensive for realistic 3-D simulations.

In the work reported here, the efficiency and flexibility of the CAFE approach has been substantially improved by incorporating four well-developed computational techniques: (*i*) separating the total field into equilibrium, incident, and scattered components, (*ii*) replacing the bilinear CAFE basis functions with high-order Legendre-polynomial basis functions, which produces a cavitating acoustic spectral element (CASE) formulation, (*iii*) introducing a simple, non-conformal coupling method for the structure and fluid finite-element models, and (*iv*) introducing structure-fluid time-step subcycling. Field separation provides flexibility, as it allows the incorporation of non-acoustic incident fields, and propagates incident waves through the mesh with total fidelity. The combined use of subcycling and non-conformal coupling affords order-of-magnitude savings in computational effort.

The effectiveness of field separation and CASE was recently demonstrated using a 1-D implementation [2]. Here, we focus on the 3-D implementation but apply the method to the 1-D canonical near-free-surface fluid-structure-interaction problem of [2]. First, the use of linearized fluid equations is validated with a Lagrangian spring-mass representation of the fluid. It is then demonstrated that the use of CASE over CAFE admits a significant reduction in the number of fluid degrees of freedom and memory storage required to reach a given level of accuracy. Finally, it is shown that comparable accuracy is achieved with and without field separation. A evaluation of the method when applied to realistic 3-D systems may be found in [3].

References

[1] C.A. Felippa and J.A. DeRuntz, "Finite Element Analysis of Shock-Induced Hull Cavitation," *Computer Methods in Applied Mechanics and Engineering*, v. 44, p. 297-337, 1984.
[2] M.A. Sprague and T.L. Geers, "Spectral Elements and Field Separation for an Acoustic Fluid Subject to Cavitation," *Journal of Computational Physics*, v. 184, p. 149-162, 2003.
[3] M.A. Sprague and T.L. Geers, "A Spectral-Element Method for Modeling Cavitation in Transient Fluid-Structure Interaction: 3-D Evaluation," *7th US National Congress on Computational Mechanics, 2003.*