AN ADAPTIVE STABILIZED FINITE ELEMENT ANALYSIS OF MULTI-PHASE FLOWS USING LEVEL SET APPROACH

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The development of efficient algorithms to understand the hydrodynamics of multi-phase flow systems is still one of the most pressing engineering challenges facing the chemical, petrochemical, nuclear, combustion and biological industries today. Overall integral characteristics of multi-phase flows are strongly influenced by the evolution of the smallest scales in the flow, including the dynamics of bubbles taking place on short spatial scales and rapid time scales. We present a stabilized finite element method to solve the multi-phase flow problems in three dimensions using a level set approach. Using this finite element framework for multi-phase flows, an effort is made to develop a three-dimensional finite element algorithm for the hydrodynamic simulation of single bubble sonoluminescence. Sonoluminescence is a phenomenon involving light emission during the implosion of an oscillating gas bubble immersed in liquid. The algorithm used to represent this complex phenomenon faces a number of challenges. It must be able to efficiently represent the fluid dynamics of both phases (liquid and gas) and accurately track the interface between them. It must also be capable of resolving the shock waves which are created during the bubble implosion.

The flow is represented by the Navier Stokes equations and the interface between the two phases is captured using the level set approach developed by Osher et al. (1994,1999). The Streamline-Upwind/Petrov-Galerkin method (SUPG) introduced by Hughes et al. (1986) is used to discretize the governing flow and level set equations. SUPG is an excellent method for problems with smooth solutions, but typically introduces localized oscillations about sharp internal and boundary layers. To improve this a discontinuity-capturing term proposed by Hughes et al. (1986) is added to the formulation. This term provides additional control over gradients in the discrete solution and considerably increases the robustness of the methodology. The method developed enables us to accurately compute the flows with large density and viscosity difference, as well as surface tension. In addition, the presented formulation allows the fronts to self-intersect, merge, break, and change topology. In the current research, a novel approach similar to the ‘‘Ghost Fluid Method’’ (Fedkiw and Aslam, 2000) is developed. The approach controls the spurious non-physical oscillations across the material interface, because of the radical change in the equation of state across the material front. Finally, an adaptive meshing strategy is implemented to study the problem in a computationally efficient manner.