PARAMETRIC STUDY OF CLOUD DYNAMICS NEAR A WALL USING A TWO-WAY COUPLED EULER-LAGRANGE MODEL

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The collapse of a cloud of bubbles near a rigid boundary is known as one of the most destructive form of cavitation. It occurs in various engineering applications such as in Shock Wave Lithotripsy (SWL) for kidney stone fragmentation, cavitating jets for biomass processing, cavitation erosion testing, oxidation, and unsteady cavitation on propellers, etc. Numerical modeling of this problem is challenging since it involves bubble-bubble, bubble-flow, and bubble-wall interactions. To address this, a two-way coupled Eulerian-Lagrangian model is used. The two-phase medium is treated as a continuum and the corresponding Navier-Stokes equations with time and space varying density are solved using Eulerian grids. The microbubbles are modeled as singularities, which follow a modified Rayleigh-Plesset-Keller-Herring equation and an equation of motion and are tracked in a Lagrangian fashion. The two-way coupling between the Euler and Lagrange components is realized through the local mixture density associated with the bubbles distribution and volumes. This method has been successfully applied and validated for two-phase bubble dynamics (Jingsen Ma, Chahine, & Hsiao, 2015) and preliminarily used for the study of cloud bubble dynamics under weak pressure excitation (J. Ma, Hsiao, & Chahine, 2014). It is extended here to study the dynamics of a cloud of bubbles under a wide range of pressure excitation amplitudes and frequencies. The effect of bubble sizes and overall void fraction is also investigated.

Simulations involving a large number of interacting bubbles in an initially spherical bubble cloud is conducted to assess the effect of the frequency of the driving pressure on the bubble cloud behavior. The resonance frequency, which results in the highest collective bubble cluster collapse is identified and results in a pressure peak orders of magnitudes higher than the excitation pressure. This occurs when the driving frequency is such that the driving pressure level is at its highest level when the collective collapse occurs. For lower frequencies, the driving pressure reaches its peak too early and is decreasing before the bubbles near wall have started their collapse. Similarly, for higher frequencies the driving pressure and the bubble volume change are not in phase and the collapse does not occur under the optimal conditions to obtain a strong concerted effect. This indicates that controlling the driving frequency is critical in practical use of cloud cavitation, e.g., in SWL. It is also interesting to point out that the optimum frequency, which results in the strongest cloud collapse is much smaller than the natural frequency of cloud derived for small amplitude oscillations (d’Agostino & Brennen, 1983)

The effect of the initial distance between the bubble cloud center and the wall is also evaluated for values of the standoff distance varying between one cloud radius and zero. When the distance is zero, i.e. collapse of a half spherical cloud centered at the wall, the strongest collapse occurs as the central bubble collapses with the largest bubble wall speed. This is due to the geometric focusing of this configuration (actually a spherical cloud collapse) where an inward propagating pressure wave collapses the bubbles.

The effects of the amplitude of the driving pressure on the resultant pressure load on the wall and other cloud dynamics properties are considered next.

d'Agostino, L., & Brennen, C. (1983). On the acoustical dynamics of bubble clouds. Retrieved from http://authors.library.caltech.edu/206/

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