Effects of uncertainty in bubble density on flow structures in shock-bubble interaction

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Abstract

The shock-bubble interaction is a physical phenomenon which occurs when a shock strikes a bubble of a different gas. In this phenomenon, the shock is refracted and reflected across the bubble surface while interfering with the phasic interface as well as other flow structures. It involves complicated interactions between shocks and flows of inhomogeneous densities, which enriches the flow structures with variety of waves and fronts.

The experiments of Hass and Sturtevant (J. Fluid Mech. 1987, pp.41-76) is a milestone on the study of these phenomena, where the characteristic velocities of different flow structures were measured quantitatively. In their experiments, the variability of flow structures were observed due to uncertainties in bubble contaminant and shock generation process. The successive numerical studies also show that the density of bubble essentially affects the flow structures throughout the whole process, and the uncertainty in bubble density may affect each flow structure in different way.

In this talk, we present the numerical analysis of the shock-bubble interaction with the uncertainty in bubble density. We considered a bubble with a Gaussian distributed uncertainty in density, and analyzed its effects on the flow structures by using a pseudo-spectral collocation method. The uncertainty is modeled as a polynomial chaos and the effects of the uncertainty are evaluated from the simulation results on the quadratic points of the random variable in bubble density.

We focus in this work on the impact of the density uncertainty in bubble on flow structures over the entire computational domain. The statistics of density field, such as mean and standard variance, are examined. It reveals that the uncertainty of bubble density affects different flow structures with different significance, which provides a global sensitivity map for the whole solution domain. Efforts have been also made to quantify the uncertainties in the motions of different waves and fronts. It is observed that the velocities of different waves/fronts might have big difference in responding to the bubble density uncertainty, which is in accordance with the existing experimental and numerical studies.