Collective behavior of MBs within a cluster under ultrasound excitation

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Background, Motivation and Objective

Isolated MBs have been shown to alter their dynamics significantly within bubble clusters. In many applications MBs exist in polydisperse clusters. Thus, a method to predict the behavior of MB clusters is needed. We propose a method to predict the collective behavior within a bubble cluster using the dynamics of its constituents in the absence of interaction.

Statement of Contribution/Methods

The inclusion of re-radiated pressure waves from oscillating MBs in the Keller-Miksis equation couples the oscillations of each MB to other MBs in the cluster. We have analyzed the behavior of polydisperse MB clusters with MBs with initial radii of 0.5um up to 1.5um for a wide range of geometric and acoustic parameters with the aid of frequency response curves and pressure and frequency dependent bifurcation diagrams.

Results/Discussion

We were able to classify inter-bubble interactions into two categories of constructive and destructive. Constructive and destructive interactions result in resonance amplification and suppression, respectively. If a resonance mode of a smaller MB aligns with a resonance mode of a larger MB in the absence of interaction; it will be enhanced when they are interacting (constructive interactions) (red arrows in Fig.1). If a resonance mode of a smaller MB does not align with any of the resonance modes of a larger MB in the absence of interaction; it will be suppressed when they are interacting (destructive interactions) (blue arrows in Fig.1). Constructive interactions can generate new resonance modes for smaller MBs in low frequencies where they do not exhibit any resonant behavior in isolation (black arrows in Fig.1). Constructive and destructive interactions are followed respectively by an increase and a decrease in the total maximum gas volume (green lines) of the MB oscillations. A special case of constructive interactions is investigated where the largest MBs will force smaller MBs into period-2 oscillations, followed by generation of subharmonics in the acoustic response of smaller MBs. We show that largest MBs even in small numbers are capable of dictating the collective behavior of the cluster. An example is presented where 4 MBs with initial radii of 1.5um force 96 smaller MBs into period doubling and subharmonic oscillations.

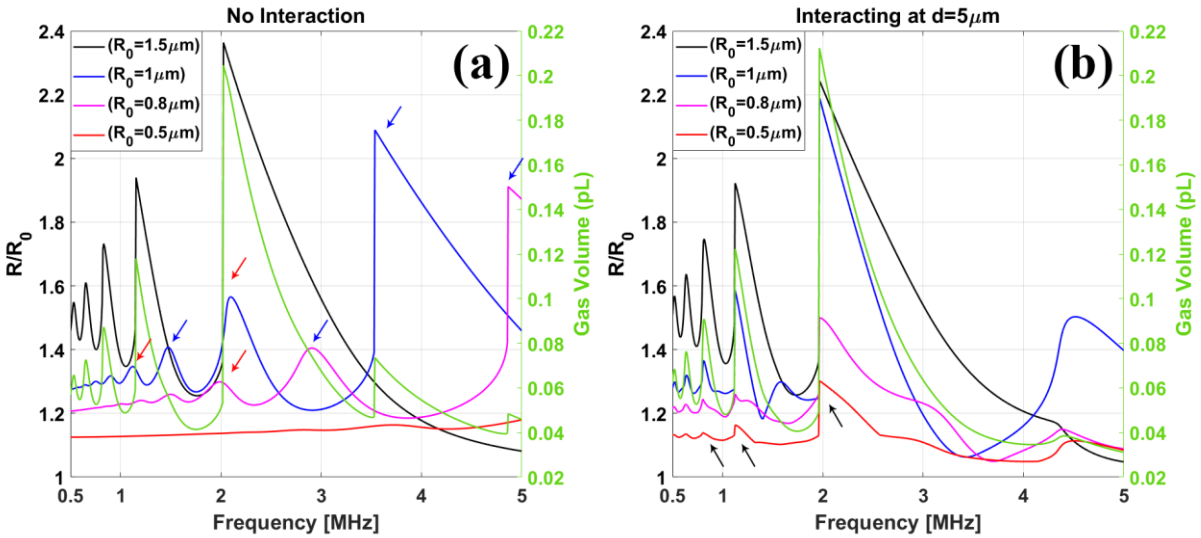

Fig.1- Frequency response graph of (a) non-interacting 4 MBs (b) Interacting 4-MB cluster at placed in a equilateral tetrahedron spatial formmation with an inter-bubble distances of 5 microns excited with an ultrasound wave with pressure amplidute of 120kPa and frequencies ranging from 0.5MHz up to 5MHz. overlayed green graphs show the total maximum gas volume of the clusters.